Electronic Engineering

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PRINCIPAL CONTENTS

A Six-Channel Electronic Recorder
J. L. Baird — Television Pioneer
An Electronic Frequency Meter for L.F.
Metal Coating on Ceramics
A Television Signal Generator — Part 3

2/- AUG., 1946

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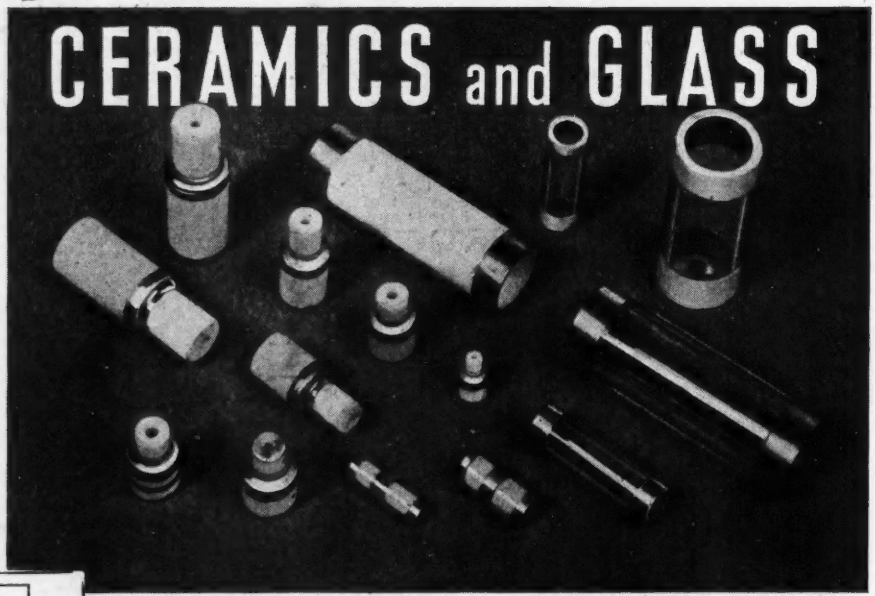

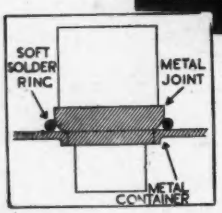

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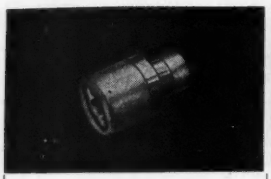

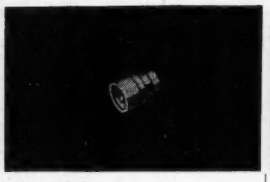

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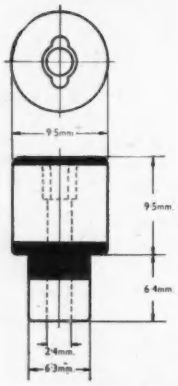

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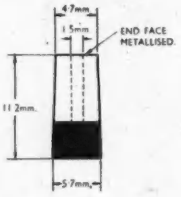

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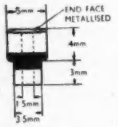

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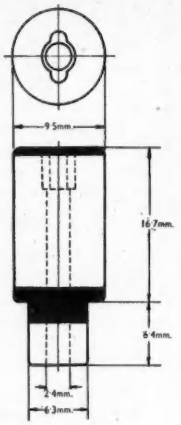

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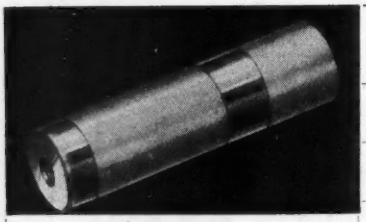

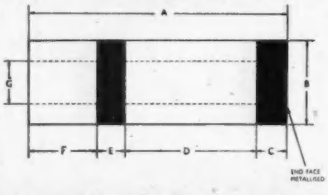

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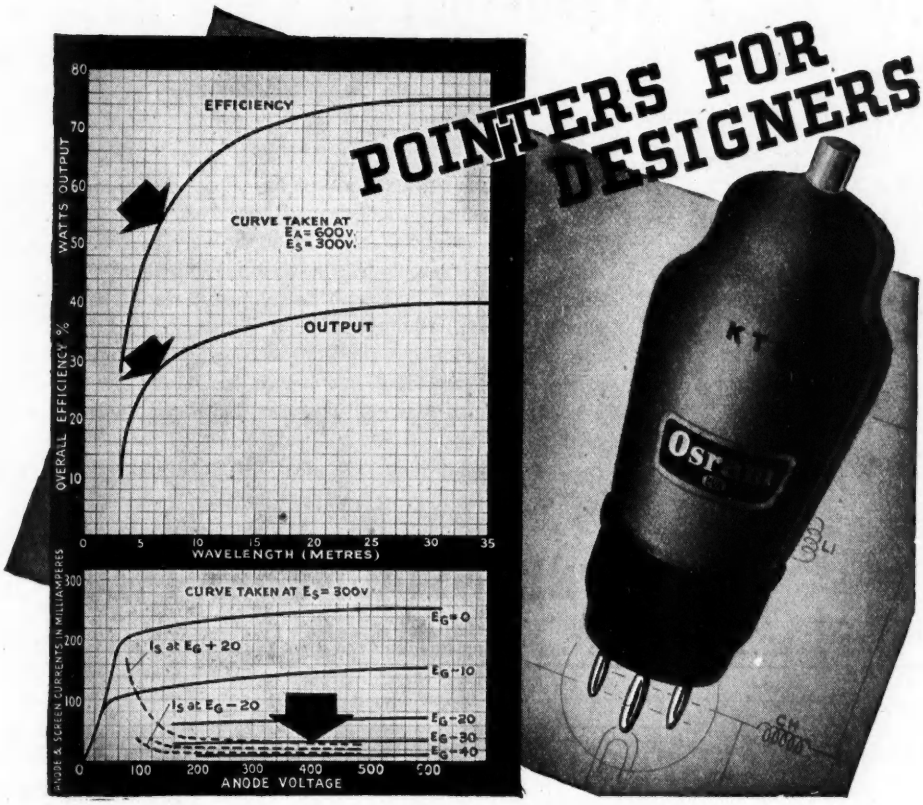

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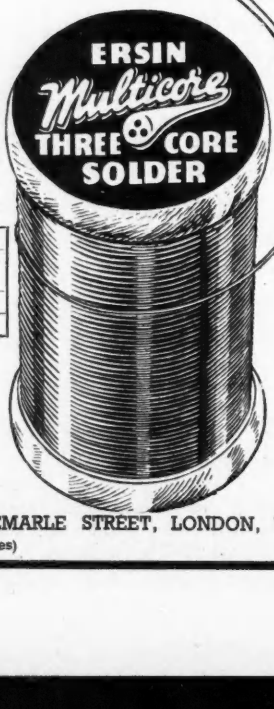

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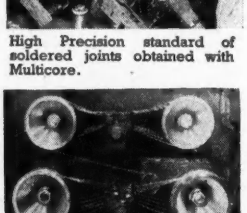

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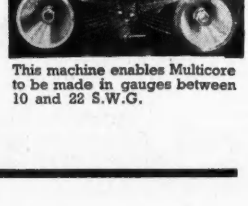

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Electronic Engineering

AUGUST, 1946

Volume XVIII. **No. 222.**

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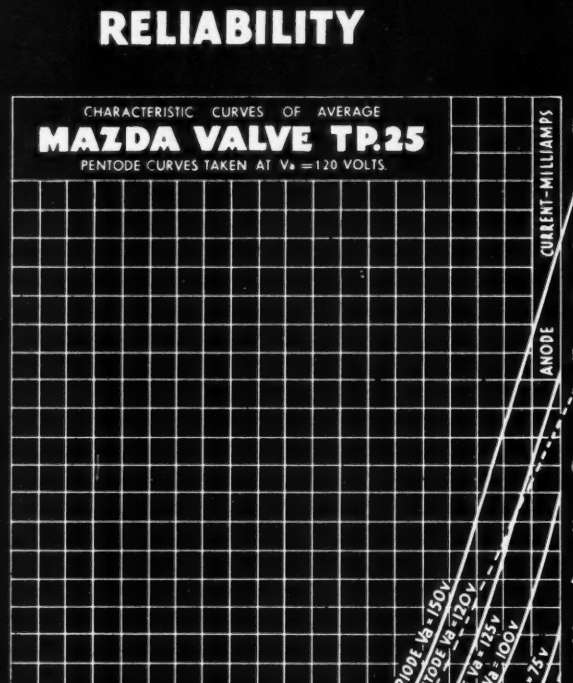

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J. L. Baird

IT would be a pity if the passing of J. L. Baird were marred by a revival of the tendency to belittle his work which was noticeable at intervals during his lifetime.

For example, a letter in last week's *Sunday Times* had this effect by pointing out that he was not the inventor of the present system of television, which is based on Campbell Swinton's proposal in *Nature*. This is, of course, true, but then neither is Campbell Swinton the inventor of television.

There are dozens of inventors of television systems. They were in existence long before Baird, and will be in existence in the future. Baird is no more the inventor of television than Marconi was of radio-communication, but they have this in common: they were the first in their respective fields to produce a practical result. And that, it is submitted, is worth more than any paper invention.

The analogy between Baird and Marconi might be worth pursuing. Marconi was hailed as the inventor of wireless telegraphy by the non-technical public and to this day his name is indissolubly associated with the development of the industry. In actual fact he was the clever realiser of other men's theories, if not inventions. The claim of Sir Oliver Lodge to be the pioneer in wireless telegraphy cannot be overlooked, and this claim was upheld in the controversy which took place from 1902 to 1906 in the electrical Press.

In television, the names of Nipkow, Rosing, and others will occur as inventors prior to Baird, but he nevertheless succeeded in producing a practical system and demonstrating it first. He would certainly have been the first to deny that he was the inventor of television as such, but he did invent several new and hitherto untried methods of transmitting pictures.

There is no reason why Baird's name should not be accorded the same merit in his own field as that of Marconi in his. His misfortune, if one may risk the statement, was that his supporters in the early days brought discredit on his work by over-publicity and premature claims. No doubt Marconi would have had the same experience if his supporters had been living in the age of 1926.

J. L. Baird was personally a modest man. He seldom appeared in public, and the greater part of his life was spent quietly in his laboratory enjoying experimenting on the subject that he had made his own. He founded a science which is giving pleasure to thousands nightly. Let there be an end to this petty disparagement.

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A 20-million Volt Betatron

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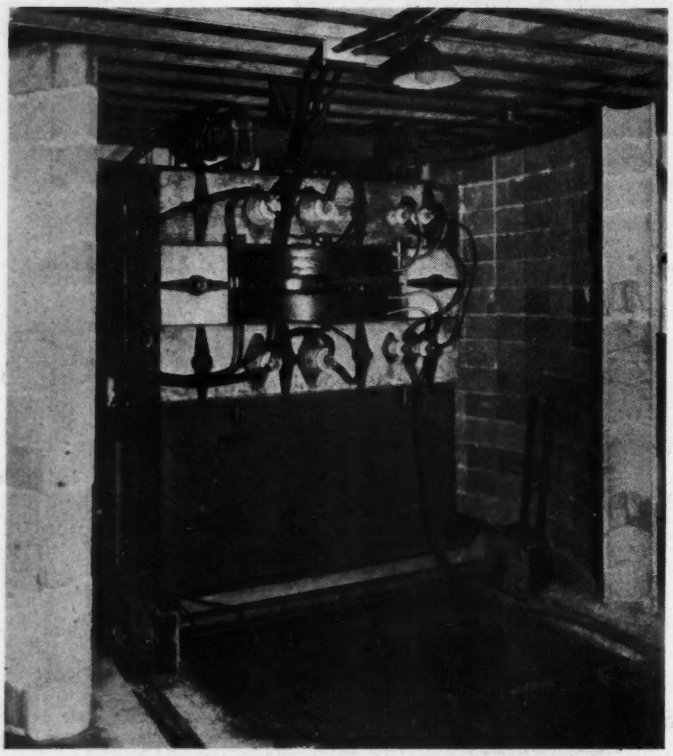


THE Department of Scientific and Industrial Research has recently made large grants to the Universities of Manchester and Glasgow for nuclear research, and Sir Edward Appleton, the secretary of the Department, has stated that the equipment to be provided under the grants will be in advance of anything in the world.

Perhaps the most outstanding item of this equipment is the Betatron, which is to be built by the Metropolitan-Vickers Co. for the use of Professor P. L. Dee, of Glasgow University. The Betatron is a device for accelerating electrons to high energy levels for the production of X-rays of great penetration, and at the present time there are only two in this country. The smaller of these is of American manufacture, while the larger was built by Metropolitan-Vickers for use in their own research department.

The enormous size of the Betatron which Professor Dee is to control may be gauged from the fact that the magnet system is to weigh 130 tons, compared with 3½ tons for the magnet of the existing Betatron.

The existing Metrovick Betatron is described as a 20 million volt apparatus, *i.e.*, it accelerates the electrons to the same energy level as if a potential difference of 20 million volts were used—and the resulting velocity of the electrons is very near the speed of light. The new Betatron is described on the same basis of comparison as a 200 million volt apparatus.

The electron acceleration is produced in a vacuum chamber, or "doughnut," situated between the magnet poles, and during the process the electrons execute several hundred thousand revolutions in the doughnut, travelling a distance of about 300 miles. A high vacuum must be maintained to prevent the electrons from colliding with stray atoms.

At the end of the accelerating period, the electrons are allowed to spiral outwards on to a tungsten target and so generate a pulse of X-rays of high penetrating power. The most penetrating X-rays hitherto artificially produced in Britain by British apparatus were those from the Bart's million volt X-ray tube, which was designed and built by Metropolitan-Vickers Electrical Company. The step from one million to 20 million volts means that the equipment as now existing in the Metrovick Research Department will have a much wider application in deep therapy treatment of cancer, radiography of metals, and nuclear research.

The 200 million volt Betatron which the company is to supply to Glasgow University will be used for fundamental nuclear research. It is not directly intended for the production of atomic energy, but at such high energies, entirely new effect of vital significance in the study of nuclear problems will undoubtedly be observed.

The accompanying illustration shows the existing Metrovick Betatron. The magnet is built of 0.014 silicon steel laminations and measures approximately 5 ft. long by 3 ft. high by 3 ft. wide. The exciting current is provided by tuning its main coils to resonance at 150 cycles with a bank of condensers which handle more than 1,500 kVA and dissipate 6 kW of heat. The power required to maintain the circulating current (106 amp. at 700 volts) is provided by a frequency-tripling transformer. This is a 50 c/s. 3-phase transformer, into which third harmonic distortion is introduced by saturation of the core, and the 150 c/s. current of 50 amp. at 700 volts is drawn from secondary windings which are connected in an open delta arrangement to remove the fundamental frequency.

The large output of X-rays obtained from the Betatron (equal to that of 3,000 grammes of radium) necessitates thick walls for the protection of the personnel operating the apparatus. These can be seen in the figure almost encircling the magnet. During operation the enclosure is completed by a wall of 18 in. thick barytes concrete bricks, which is moved up on a truck.

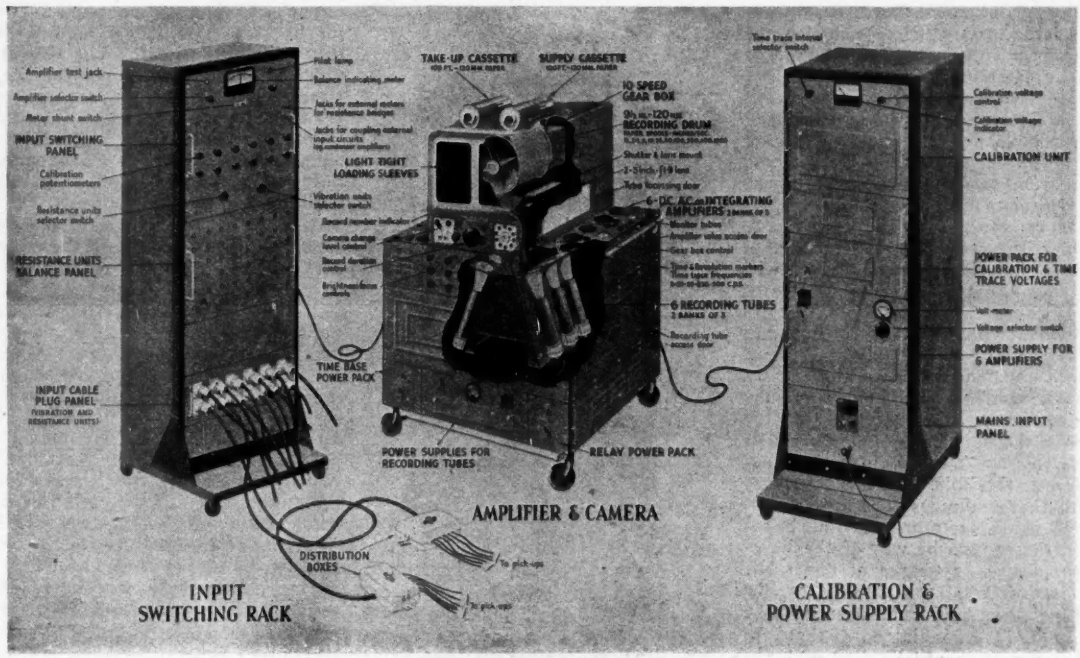


Fig. 1. General view of equipment.

A Six-Channel Electronic Recorder

By M. SCOTT*

THE equipment described in this article was designed in accordance with a specification issued by the Royal Aircraft Establishment to meet the requirements of an electronic recorder to assist the designers of aircraft in their investigation and measurement of the strains, and amplitude and velocity of vibrations occurring in different parts of aircraft.

The measurement of vibration or strain in aircraft propellers, engines, frames, wings, undercarriages, etc., while fundamentally the same in principle in each case, often necessitates an entirely individual technique in making the actual measurement. The specification accordingly called for a design of recorder sufficiently flexible to cover the various existing requirements and sufficiently flexible also to take into account some possible future requirements.

General Description

Essentially the six-channel recorder consists of six separate cathode-ray tube oscilloscopes built into a single unit named the camera unit. The traces appearing on the six cathode-ray tube screens are focused by means of two lenses on to a drum of 30 in. periphery, around which is wrapped photographic paper having a width of 120 mm. The drum is driven by an electric motor through a 10-speed gearbox, which allows a wide range of paper speeds from half inch to 1,000 in. per sec., the maximum length of paper being 100 ft. Two rack type units, in addition to the camera unit, are provided, one containing the input switching circuits and the other containing the calibration unit, time marking unit and power supplies for the amplifier.

The whole equipment has been designed for the investigation of stresses and strains in grounded aircraft, but by suitably designed transmitting and receiving equipment the required information for recording in the camera unit could be received by radio from aircraft in flight.

The Camera Unit

The camera unit, which is the vital part of any photographic recording equipment, has been designed, as mentioned above, to allow for a wide range of paper speeds and to enable the length of record taken to be varied from 30 in. to 100 ft. Obviously a drum camera alone is inadequate for use over this range of paper lengths and consequently a continuous feed system of suitable design is required. With a continuous feed camera using 120 mm. wide unperforated paper, certain practical considerations become progressively more difficult as the paper speed increases. For reasons of economy in photographic paper, the latter must remain stationary until just before the event to be recorded takes place, at which time the paper must be accelerated up to the required speed in the shortest possible time; the paper must then be decelerated also in the shortest possible time if there is to be a similar economy in paper at the end of the trace recording. The strain transmitted to the paper and associated driving mechanism during acceleration and deceleration makes it desirable that the paper speed should be kept as low as is consistent with the accuracy required for the recording. Fortunately the greater

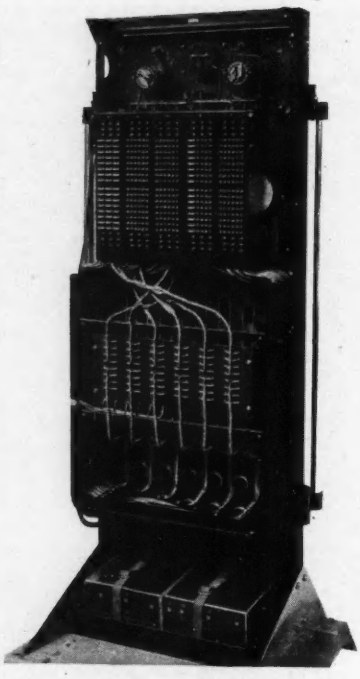
* Cinema-Television, Ltd.

majority of vibration and strain measurements requiring long lengths of paper can be undertaken at speeds not greater than 200 in. per sec., while measurements requiring high-speed recording can be satisfactorily taken on paper lengths in the region of 30 in. It was decided to combine the drum camera and the continuous feed camera into a single unit.

If reference is made to Fig. 1, which illustrates the equipment as a whole, the camera compartment will be seen situated in the top centre of the camera unit. Two armholes provided with light-tight sleeves are provided to enable daylight loading, while situated on top of the camera compartment, immediately above the drum, are two paper cassettes, the one on the right being used as a paper reservoir and the one on the left containing the take-up spool for use with the continuous feed mechanism.

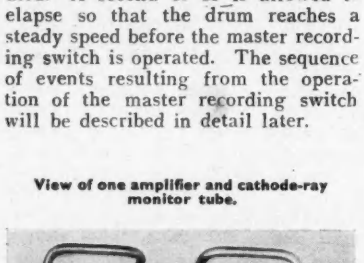
When the operator inserts his hands into the camera by way of the light-tight sleeves, a tongue of paper left projecting from the cassette can be pulled down and guided around the drum. If it is intended that the camera unit should be used with the drum attachment, the paper can be cut to the correct length, after being positioned around the drum, by means of a guillotine, and can then be fastened to the cylindrical surface of the drum. If the continuous feed attachment is to be used, the paper is guided first around the drum and then into a clip attached to the take-up cassette, which is driven via a slipping clutch from the drum shaft. The reason for the slipping clutch is obvious when it is realised that as paper is fed into the take-up cassette the effective diameter of the take-up spool is continuously increasing and consequently is tending to take up paper at progressively increasing speed. It is therefore arranged for the take-up spool to rotate at a higher speed than the drum, while the clutch is adjusted to slip if the take-up spool endeavours to pull the paper through the continuous feed mechanism faster than it is being fed by the main driving mechanism.

The operation of the camera, when it is used for recording on short lengths of paper by means of the drum, is simple. When the recording paper has been secured to the drum, the required speed is selected and the drum motor is started. When the starter switch is depressed, a pair of contacts opens the camera shutter which is electro-magnetically operated. A second or so is allowed to elapse so that the drum reaches a steady speed before the master recording switch is operated. The sequence of events resulting from the operation of the master recording switch will be described in detail later.



Rear view of input switching rack with dust cover removed.

View of one amplifier and cathode-ray monitor tube.



The operation of the camera used for recording on long lengths of paper is also simple, but slightly different. When the paper has been attached to the take-up cassette, as previously described, and the required speed has been selected, the hand-operated lever is moved from the position marked DRUM to the position marked CONTINUOUS FEED. This lever moves a pair of driving rollers to within 1/16 in. of the drum. The required recording paper length is selected by turning the knob marked FOOTAGE INDICATOR to the appropriate number of feet on the dial. Next the drum motor is started and the master recording switch depressed. From this time onwards, until the record is finished, the camera is controlled automatically by means of a rotating mechanical switch driven from the gearbox and running at the drum speed. Synchronisation of the various events occurring during the recording is also obtained by means of this switch.

Fig. 1 shows the position of the six amplifiers feeding the six cathode-ray tubes. Incorporated in each amplifier is a small cathode-ray tube used for visual monitoring before or during the actual recording.

The amplifiers themselves can be operated as D.C. amplifiers with a frequency response from zero to 10 kc/s. or as A.C. amplifiers with a frequency response from 5 c/s. to 10 kc/s., the gain being controlled by means of negative feedback. The maximum gain is 20,000 and this can be reduced to 40 by means of a ten-step attenuator, each step of one switch bank giving half the gain of the preceding step. Attached to the attenuator switch is another ten-step switch bank which is used to select one of a number of accurately known voltages for connexion to the amplifiers at the beginning of each record for calibration purposes, the waveform being rectangular in shape and having a frequency of 500 c/s. A four-way selector switch on each amplifier enables them to be operated as follows: Each amplifier can be operated firstly, as a D.C. amplifier; secondly, as an A.C. amplifier; thirdly, as an integrating amplifier; the input voltage required to produce a constant output voltage being proportional to frequency within ± 2 per cent. from ·5 c/s. to 10 kc/s.; and fourthly, as an integrating amplifier, the input voltage required to produce

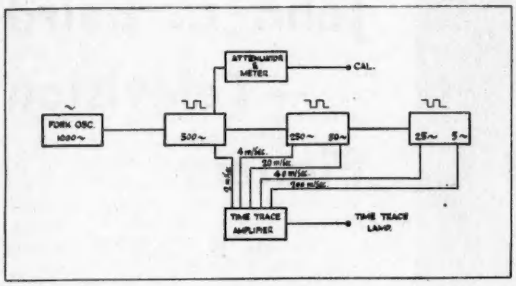


Fig. 2 (left). **Block schematic of calibration and time marking unit.**

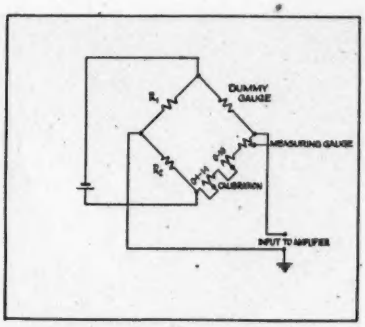


Fig. 3 (right). **Basic bridge circuit.**

a constant output voltage being proportional to frequency within ± 2 per cent. from 50 c/s. to 10 kc/s.

The short-term drift of the cathode-ray tube spot due to voltage variations is limited to 0.02 in. in three minutes and long-term drift is limited to 0.25 in. in one hour. The amplifier circuit has been designed to be substantially independent of voltage variations and high-stability resistances are used throughout to minimise the effects of ambient temperature changes.

Calibration and Time Marking Unit

The time trace unit is used to provide a series of timing marks, each extending across the width of the paper, at 1/5th, 1/25th, 1/50th, 1/250th and 1/500th sec. intervals, with an accuracy better than 1 part in 10,000, the required frequency being selected by means of a switch on the front panel of the unit.

The illumination for working is produced by means of a gas discharge lamp, which produces a bright thin line of light focused on the recording paper by means of a cylindrical lens.

The high voltage pulses required for the lamp are obtained from a specially designed induction coil connected in the anode circuit of a time trace amplifying valve. The manner in which this valve obtains its signal is shown in the block schematic (Fig. 2) of the whole of the calibration and time marking unit. This unit comprises essentially a 1,000-cycle tuning fork oscillator which feeds into a scale-of-two frequency divider. The output from this frequency divider is fed firstly to a calibration attenuator and meter unit; secondly, to two further frequency dividers connected in series; and thirdly, to the time trace amplifier. Each of these latter frequency dividers provides a division of frequency by 2 or 10, allowing any selection of division by 2, 10, 20 or 100. The four outputs from these two frequency dividers, together with the output from the scale of two frequency dividers, are fed to the input of the time trace amplifier, which in turn feeds the time trace lamp.

Because there are five different timing frequencies it is necessary to be able to distinguish one from the other, and this is done by photographing a small disk engraved with numbers corresponding to the frequency in cycles per second. When operating the selector switch to obtain the required frequency, a number of pulses are applied to an electromagnet which drives the disk around to the correct position. An image of the number on the disk is then produced on the paper by means of a 2-in. f 4.5 lens. The light source is a small gas discharge lamp similar to the one used for the timing marks. The lamp is required to flash once per record, and the high voltage necessary for this is obtained by charging a condenser to 2,000 volts and then at the appropriate moment discharging it through the lamp. Light from this source is also used to photograph a counter giving the number of records which have been taken, the same lens being used for both images.

The calibration voltage for the amplifiers, as can be seen, is obtained from the first frequency dividing unit at a frequency of 500 c/s., the meter being used to adjust accurately the output voltage amplitude to within ± 1 per cent.

The output voltage from the first frequency dividing unit is divided into ten fixed voltage steps which are fed into the switch on the amplifier chassis already described in the paragraph on amplifiers.

The Input Switching Rack

This unit enables a large number of wire resistance strain gauges or electromagnetic generator type vibration pick-ups to be connected by means of multi-bank selector switches to the amplifiers as required.

If vibration measurements are to be made, a total of 48 pick-ups can be connected to the input sockets at the bottom of the rack and selected in groups of six by the switches for connexion to the amplifiers.

When making strain measurements it is intended that the resistance strain gauges should form part of two arms of a resistance bridge circuit, one gauge being used for measuring the strain in terms of changing resistance and the other gauge being a dummy which is placed near the measuring gauge to counteract the effect of local changes of temperature. A total of 48 measuring gauges and 48 dummy gauges can be connected to the input sockets and selected in groups of six pairs for connexion to the amplifiers.

As a total of 48 measuring gauges can be connected simultaneously to the unit, to save time in rebalancing the six bridges each time a new group of six measuring gauges is selected for recording, a panel containing 48 pre-set balancing potentiometers is provided, all of these being adjusted before any records are taken.

Reference to the circuit diagram (Fig. 3) of the resistance bridge shows that the arm containing the measuring gauge has in series with it a resistance variable in 10 accurate steps of 1 ohm from 0 to 10 ohms and an accurately calibrated resistance which is continuously variable up to a maximum of 1.1 ohms; these resistances are used for calibration purposes.

(*Continued on page 261.*)

One of the last photographs taken of J. L. Baird in his laboratory.

John L. Baird — Television Pioneer

By B. CLAPP

The author of this appreciation was Mr. Baird's first technical assistant and maintained close association with him for many years

JOHN L. BAIRD, who died on June 14, 1946, aged 58, at his home in Bexhill-on-Sea, was a typical inventor who before he became famous had experienced the hardships and difficulties of life. He was the son of a Scottish minister and started life with very little means. At one time he was interested in a jam-making factory in Jamaica but soon abandoned this in favour of technical work. He returned to London where his fertile brain began to explore the possibility of television.

So determined and certain was he of the future of this new science that in the early 1920's he worked in a garret in Frith Street, London, frequently day and night and often without food or money. By his personality and Scottish doggedness he impressed many members of the radio and electrical industry with his ideas, some of whom helped him by lending the apparatus and equipment so necessary for his experiments and then conveniently forgot to send in a bill or ask for the gear to be returned.

With these sundry pieces of equipment and some string and plasticine he progressed so far until he came to a complete standstill for want of funds. He was almost at the end of his tether and for some time had barely sufficient food to keep him going when he met in a London street an old friend. He told him all about his work, and, what was more important, his "visions"—which have turned out to be so true—of the future of the transmission of pictures of living images over a distance by wire or radio.

So impressed was this friend that he immediately set about raising some funds and in due course Baird gave a demonstration in January, 1926, in his small room in Frith Street, London, to some forty members of the Royal Institution. *The Times* of January 28 stated in an article on the demonstration:

"First on a receiver in the same room as the transmitter, and then on a portable receiver in another room, the visitors were shown recognisable reception of the movements of the dummy head and of a person speaking. The image as transmitted was faint and often blurred, but substantiated a claim that through the 'Televisor,' as Mr. Baird has named his apparatus, it is possible to transmit and reproduce instantly the details of movement, and such things as the play of expression on the face."

As a result of this positive evidence of the possibilities of television, a small company was formed known as "Television Limited" and opened new offices and laboratories in Upper St. Martins Lane, and it was here I first saw John Logie Baird early in 1926 where he was carrying on his experiments without any technical assistance whatever. Even at this stage he was fully confident of solving the main problems and perfecting the science.

A few months later, towards the end of 1926, I became his first technical assistant and was connected with him very intimately for many years.

Even during the most exciting moments in our experiments he was a most considerate man, and although time meant nothing to him—night being the same as day, Sundays the same as weekdays—he was always most thoughtful for his staff and insisted that while working long hours they had adequate food and drink. As a Scot he dispelled the idea that as a race they are mean—he was most generous.

In May, 1927, Baird suggested that a picture should be sent from London to Glasgow by wire. A room was en-

gaged in the Station Hotel, the necessary telephone lines reserved, and the experiments commenced. He was always confident that any demonstration would be successful, and on May 24 Dr. Taylor Jones, who was a Professor at Glasgow University, came to the hotel and saw an image of living people being transmitted from the studio in London. This was an achievement, and the first long-distance transmission of television ever made.

John L. Baird never really came out of the clouds, and did not realise all the detail work necessary to carry out some of his ideas. He staggered me one day in September, 1927, by walking into the laboratory and saying in that quiet slow drawl of his, "Can you sail for America tomorrow?"

He had a sudden urge to send a television picture across the Atlantic to New York and completely lost sight of the fact that there were such things as passports, visas, and passages to be booked, also a fair amount of equipment to be got together and packed without any outside assistance. Arrangement had to be made for operators to run the radio transmitter situated in my house at Coulsdon, which was to be used as the radio link, being connected by land line to the Baird studios and television scanning equipment in London. I was still his only technical assistant, and the whole project was to be a complete secret until the time was ripe to demonstrate in New York. Actually, the trip started a week later.

The tests were successful and the proposed demonstration was given in New York on February 9, 1928, resulting in two-inch headlines in the New York papers, and the following remarks:

"Baird was the first to achieve television at all over any distance. Now he must be credited with having been the first to disembody the human form optically and electrically, flash it piecemeal at incredible speed across the ocean, and then reassemble it for American eyes.

"His success deserves to rank with Marconi's sending of the letter 's' across the Atlantic—the first intelligible signal ever transmitted from shore to shore in the development of transoceanic radio telegraphy. As a communication, Marconi's 's' was negligible; as a milestone in the onward sweep of radio, of epochal importance. And so it is with Baird's first successful effort in transatlantic television."

A few weeks later a picture was received in mid-Atlantic on the *Berengaria*, and witnessed by the captain and other officers of the ship. The accompanying photograph was taken on that occasion. The chief radio operator was able to see his fiancée in the studios in London.

All this publicity enabled Baird to obtain the necessary finance to float a new company, known as Baird Television, Ltd., and from then on he went ahead with his experiments until he convinced the B.B.C. that even 30-line television, although still somewhat crude, had programme value, and a series of experimental programmes were undertaken in September, 1929, which were transmitted from Baird studios at Long Acre, thence to the B.B.C. by land line and broadcast on the normal sound wavelengths of that station.

The B.B.C., of course, later started their own 30-line transmission direct from the studios at Portland Place, using Baird equipment and system entirely.

This pioneer work done by Baird, and his persistence and foresight in convincing the B.B.C. and Government that there was something in it after all, was not far wrong, and was the incentive to other concerns and inventors to hurry on with their experimental work based on his original ideas.

In the very early days of his work on television he had many setbacks, both financial and due to ill-health, but none of these had the effect of embittering him or in any way damping his enthusiasm, and he always remained a most courteous and considerate man.

In 1931 arrangements were made to attempt to televise the Derby and to transmit it on a screen at a London cinema. Three separate 30-line zones were used giving the whole picture the equivalent of 90-lines. Very good results were obtained and the whole of the audience were able to see the finish of the race and the owner was clearly seen leading in his winning horse.

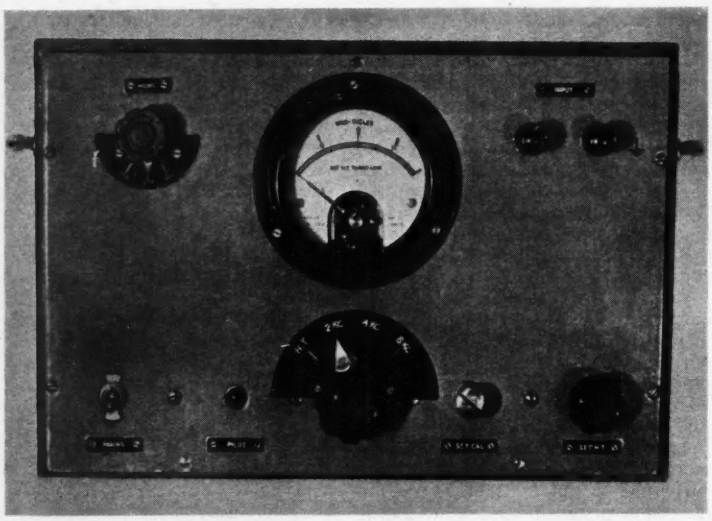
A typical instance of Baird's anxiety that everything should go smoothly was shown by the following instance. He came on to the stage behind the screen where the television receivers were installed just before the start of the race, and as the horses came into view on the screen J. L. B. exclaimed, "Phew!" with relief that all was well, and only by my placing a chair beneath him was he prevented from sitting on the stage.

With the passing of John Logie Baird, the world has lost a great inventor, whose achievements have not been fully appreciated. There is no doubt that he should have had some official recognition for the pioneer work he had done.

Taken on board the *Berengaria* during the first transatlantic television transmission.

Electronic Frequency Meter for L.F.

By W. A. ROBERTS



THE methods most commonly used for the frequency measurement of L.F. tones depend either upon comparison with known tones or upon the use of a calibrated frequency bridge.

In comparison measurements the unknown tone is compared with the output of a calibrated variable frequency tone source. The unknown frequency is identified by obtaining zero-beat or by obtaining stationary Lissajous figures, from the geometry of which the frequency relationship between known and unknown tones is apparent.

Alternatively, the L.F. tone may be distorted to produce harmonics at R.F. by squaring or pulse generation and an R.F. harmonic then compared by zero-beat methods with the output of a variable frequency R.F. oscillator.

In bridge methods, the bridge used is frequently a derivative of the Wien bridge and one or more of the elements are made variable, the control dial being calibrated in frequency. The bridge is adjusted for a null (usually aurally, because of the presence of harmonics which are not eliminated at balance), and the frequency is read from the setting of the calibrated dial. This method has been simplified by the introduction of decade-type bridges.

Comparison and bridge methods are not convenient where a large number of measurements have to be taken at short intervals. Moreover, none of these methods is capable of showing the instantaneous frequency of an unstable or varying tone.

The instrument to be described is a direct-reading electronic frequency meter. It shows instantaneous frequency on a calibrated meter scale in much the same way that a voltmeter shows the instantaneous value of voltage applied to it. The electronic frequency meter is applied across a circuit element in which the frequency exists and its indicating meter immediately shows the frequency.

Successive measurements of a number of different tones can therefore be obtained with the greatest ease and without the adjustments necessary in comparison and bridge methods. The extent, sense and speed of any variations occurring in the input frequency are immediately apparent.

The particular model to be described is a simple transportable one for general laboratory use. Instruments of greater or lesser elaboration, to meet a wide range of specifications, can be designed on the same principle.

The specification of this instrument is as follows:—

Input impedance, 100,000 ohms.

Frequency ranges, 0 to 2,000 c/s.; 0 to 4,000 c/s.; 0 to 8,000 c/s.

Overall accuracy, 2 per cent. of full scale (the full accuracy of a B.S. Grade 1 meter).

Minimum input voltage, 0.5 V r.m.s. Input can then be increased to 50 V without any change in meter reading.

Input waveform, unimportant.

Valves, 3 pentodes, 1 power rectifier.

Power requirements, 200/250 V, 50 c/s., 50 W.

Dimensions, 14 in. × 9 in. × 7 in.

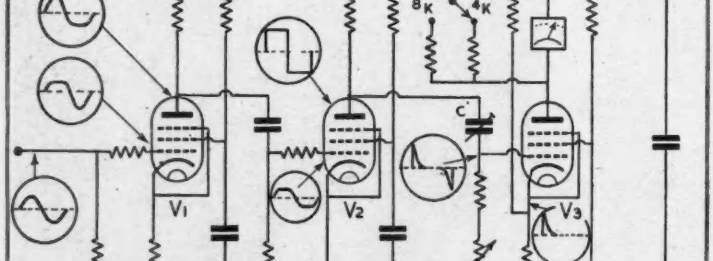


Fig. 1.

The basic principle on which the frequency meter operates can be illustrated by reference to Fig. 1.

In a direct-reading frequency meter a most important point is to ensure that the meter indications are not affected by changes of signal-input voltage over the specified working input range. V_1 and V_2 are therefore operated as limiters, producing a square-topped wave of fixed amplitude. The square wave is then differentiated to produce a pulse.

The circuit constants of V_1 and V_2 are arranged to give maximum amplification and to limit on grid and anode with small inputs. Each stage has a high anode load, no static bias, and a grid series resistance.

It is the positive half-cycle of the original input cycle which is of greatest interest throughout the circuit. This positive half-cycle will be partially squared by rectification at the grid of V_1. It appears as an amplified negative square wave at the anode of V_1 and is applied to the grid of V_2.

Its peak amplitude is now of the order of 40 volts so that the grid of V_2 is swung far beyond cut-off. The input waveform is consequently squared much earlier, and, with further positive limitation at the anode of V_2, something very close to a true square wave is available at the anode of V_2.

If this square wave is referred back to the original sine wave by means of a C.R.O., it can be seen that squaring commences only a few microseconds after the commencement of the input cycle. The developed waveform is therefore a very close approximation to a perfect square wave and in practice can be considered as such independently of frequency up to the limits of the range served by the instrument.

When a square wave is applied to an RC series arrangement as in Fig. 2 the output voltage obtained across R is a pulse, the shape and magnitude of which are given by

$$v = Ve^{-t/CR} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(a)}$$

The differentiating circuit of Fig. 2 is used in this frequency meter between the anode of V_2 and the grid of V_3. It is driven by the approximately perfect square wave at the anode of V_2. Referring to Equation (a), C and R are physical constants chosen to produce a brief sharp pulse. V is maintained constant by the limiting action of the circuit. It follows that

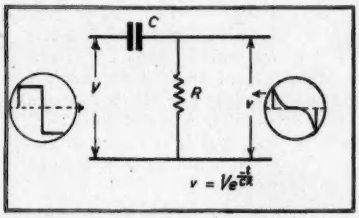


Fig. 2.

the elements of equation (a) are constants and, irrespective of input frequency, a standard pulse is produced, constant in duration and shape.

This pulse and its negative counterpart are applied to the grid of V_3. V_3 has a large negative bias which puts the valve just beyond cut-off.

In the static condition there is no current through V_3. The negative pulses applied to the grid produce no change in this condition because they merely put the grid more negative while they last. The brief positive pulse releases the space current of the valve for the duration of the pulse at the point where it crosses the cut-off bias. A pulse of anode current flows.

There is one positive grid pulse for each cycle of input frequency and there will be a succession of anode current pulses in V_3 at a repetition frequency equal to the original input frequency. The anode current meter will indicate the average value of the anode current. If now the input frequency is doubled the repetition rate of the standard pulses will be doubled. As a result, the scale of the meter can be linearly calibrated in frequency.

Various supplementary considerations arise when the principle is put into practice.

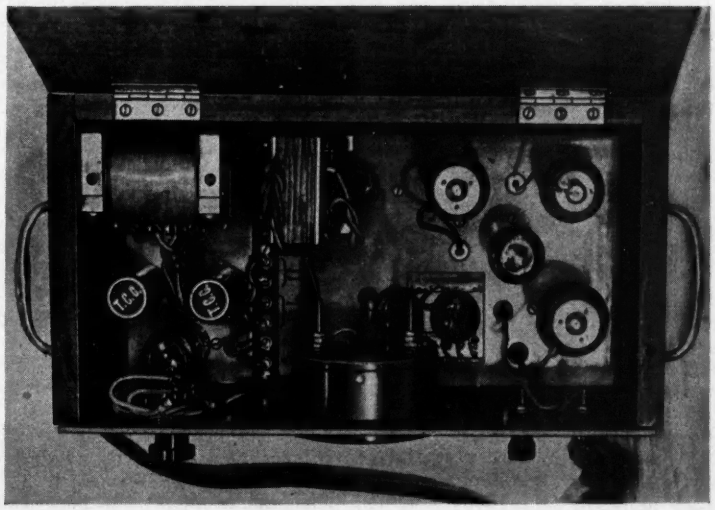
The standard pulse on which the operation of the instrument depends is obtained only when the square wave at the anode of V_2 has its full standard and maximum amplitude. As the amplitude of the original input signal is decreased there will come a time at which the product of the gains of the first two stages is just insufficient to obtain positive limiting at the anode of V_3.

Below this critical value of input voltage the pulses will no longer be standard and the meter reading will decrease with decrease of input voltage. The decrease of meter reading which occurs between the critical value of input voltage and zero input voltage will be called the "run-off."

It is desirable that the minimum input voltage which will produce standard pulses should be as low as possible. This implies that the total gain of the first two stages should be as high as possible and indicates the use of pentodes. In this model, ACSP3 pentodes are used for V_1 and V_2. V_3 is an AL60.

A resistance of 30,000 ohms is put in series with the input of V_1 for the sole purpose of maintaining a high input impedance. The measured input impedance is then greater than

Interior view of frequency meter.



100,000 ohms at all frequencies and is of the order of a megohm at the critical input voltage. With the 30,000 ohms omitted the critical input voltage is of the order of 0.2 V instead of 0.5 V. Very much lower critical voltages can be obtained by the addition of another stage of amplification before V_1. For the writer's purposes it was not found desirable to decrease the critical voltage as much as this because noise and induced voltages at the input then sometimes operate the instrument. 0.5 V appears to represent a reasonable compromise for general laboratory use.

The upper limit of 50 volts input is quoted as giving the highest input which it is reasonable to apply to the grid of the ACSP3 via the dropper. The reading of the meter is unaffected by much higher input voltages, but such operation is not recommended. When frequencies at high voltage must be measured it is quite easy to insert a dropping resistance in series with the leads to the instrument, and this will at the same time increase the effective input impedance as seen by the source under measurement.

Where it is possible to choose the input voltage, values between 1 and 2 volts are as suitable as any.

Ageing and deterioration of the two ACSP3 valves have no effect whatever on the calibration of the instrument. They can also be changed freely without calibration shift. Deterioration in these valves is evidenced by an increasingly higher critical voltage being required to operate the instrument.

The introduction of a small degree of differentiation, or pulse generation, between V_1 and V_2 gave a small improvement in the sharpness of the critical run-off point.

The anode resistances of V_1 and V_2 should be as high as possible having regard to adequate high-frequency response in the amplifier. If they are increased excessively the sharpness of the critical voltage is adversely affected, although the critical voltage is lower.

The condenser C in the main pulse generating circuit is a physically small ceramic variable of approximately 60 $\mu\mu$F maximum capacity. This variable provides a control of pulse amplitude and duration. It is used in initial calibration to set the anode current of the pulsed valve exactly to full-scale meter deflection on the unshunted 2,000 cycle range (a frequency of 2,000 cycles being applied at the input to the instrument). The CR product was not found to be very critical, but it is easier to maintain high-frequency response if C is kept small.

The resistance in the pulse generating circuit consists of a fixed portion of 50,000 ohms and a variable portion of 10,000 ohms. The variable portion is a preset potentiometer the control of which is available behind a mask on the front panel and labelled "SET CALIBRATION."

The scale of the meter can, if desired, be checked occasionally against a standard frequency and the "SET CALIBRATION" control can be used to effect any necessary correction. Adjustment at one frequency is correct for all since the scale is linear; there is no ageing of scale law. Scale linearity is fundamental to the system unless deliberately avoided by circuit additions.

In practice adjustments of scale have not been found necessary in some three months of use. On one occasion the instrument was left on for seven days continuously with input from a 1,000-cycle standard. The maximum errors observed were plus and minus 0.5 per cent.

In this particular model the peak value of the pulse applied between grid and cathode is 5.0 volts. The peak cathode current is 4.8 mA and the average anode current at 2,000 cycles is 200 μA. The standard pulse at the output of the differentiating circuit is of 25 microseconds duration. The pulse applied to the grid of V_2 (the AL60) is 20 microseconds in base duration.

As might be expected, a much larger anode current (some two to three times greater) can be obtained with a given pulse input if the cathode resistance of V_2 is substantially bypassed. In the present case the current with an unbypassed cathode was adequate and the bypass was omitted because it was considered that the negative feedback so obtained might be of assistance in stabilising the operating characteristics of V_2.

The 200 μA meter used has a resistance of 1,400 ohms. Values of resistance up to several thousand ohms can be tolerated without changing the performance. With a given type of meter movement, where the full-scale deflection and field intensity are fixed it is desirable to have a higher rather than a lower resistance coil. The greater number of turns per volt gives increased torque for a given current change. The restoring springs can then be stronger and the whole movement is more robust and less subject to pivot errors.

The quoted instrument accuracy of 2 per cent. is the accuracy of a B.S. Grade 1 meter, and this is the limiting factor. It will be recognised that the performance obtained from a reputable make of meter is in general better than this, but no better figure can legitimately be quoted. In initial calibration the frequency meter shunts are adjusted to give high accuracy at the midscale reading, so distributing the error evenly over the meter. In such a case it is recommended that subsequent calibration corrections should be made at frequencies near midscale on one or other of the ranges.

With a 200 μA meter and a first range of 2,000 cycles the change in H.T. load from zero to 8,000 cycles is 0.8 mA (all due to the change in the anode current of the AL60). If a meter of greater full-scale deflection is used, with the same ranges, the total H.T. load change will be correspondingly greater and may be sufficient to upset the voltage regulation of a simple power supply. The effect will be a contraction of scale towards 8,000 cycles.

By the principle used, the reading of the meter is dependent upon the value of the H.T. voltage. Stabilisation of the H.T. supply was out of place in a transportable model such as this. One position of the frequency-range switch is therefore labelled HT and turns the meter into a voltmeter across the H.T. supply. A front panel control is provided by which the H.T. can be adjusted to a reference figure marked on the meter scale. This virtually corresponds to the "ADJUST ZERO" control found on most valve-voltmeters (to which this instrument can be likened in a number of ways).

If the meter is replaced by a resistance, then a D.C. output voltage proportional to frequency is available and the utility of the circuit can be extended to new applications.

Metal Coatings on Ceramics

By E. ROSENTHAL, Dr.Ing., A.M.I.E.E.

THE coating of ceramic surfaces by metal layers is a problem with which insulator manufacturers have been dealing for many years. One of the first applications of metal coatings was in connexion with high-voltage insulators. They have frequently been coated near the edges of the caps by means of the Schoop spraying process. The purpose of these metal coatings is to assist better field distribution.

The same process is still being applied with satisfactory results in the case of high-voltage power bushings near the edges of the central flanges, and also for high-frequency high-voltage insulators. The sprayed coating is very rough and not homogeneous. Where, apart from high electrical conductivity, a very dense and firmly adhering layer is required for subsequent soldering, the spraying process is not as good as burning-on layers of precious metal or embodying reducible non-precious metal oxides in the porcelain glaze.

The hot metal particles thrown on to the ceramic surface by the Schoop pistol do not combine chemically with the surface; they adhere only mechanically. The adherence is improved if the coating is applied to a glaze having a lower softening temperature than the porcelain body. The glaze has to be roughened by a sand-jet before the metal coating is sprayed on.

Not all metals adhere equally well; copper for instance does not adhere very firmly. Ground layers of other metals should first be applied. A copper layer is subsequently sprayed on. By using a glaze in which metallic particles are embodied the adhesion can be further improved. The Schoop process is also suitable for reinforcing burnt-on precious metal layers.

In the case of large insulators coatings produced by spraying are more convenient than burnt-on metal coatings because in the latter case the articles after application of the paint have to be fired to a temperature of between 650° C. and 850° C. as described later. This is an expensive process for large articles.

Spraying is not suitable for coatings of accurate dimensions such as are often required in high-frequency engineering. It is also very difficult to cover the inside holes of tubes and the insides of flask-shaped articles by this process.

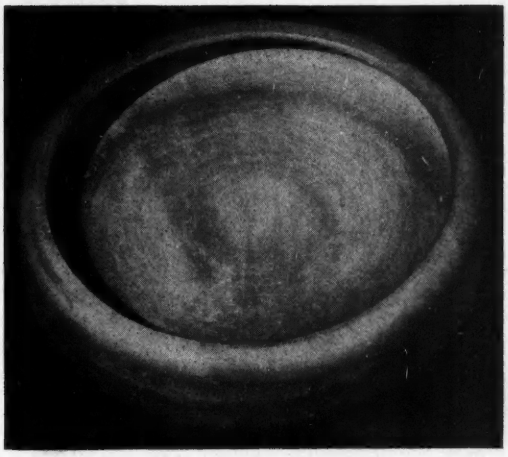


Fig. 1. Silvered ceramic disk for high-frequency capacitor.

Another method of coating ceramics is silvering by way of cathode volatilisation. The principle in this process is to use as a cathode the metal to be volatilised under the influence of a glow discharge operated at 900/1,200 volts. The vapour emanating from the cathode is then allowed to condense on the cool surface of the ceramic article placed near to the cathode. Current and voltage are regulated in such a way as to keep the wires continuously red-hot but well below the melting point of the silver. The coating is formed from a cloud of metallic vapour emitted from the silver-cathode wires. If one wants to obtain coatings of accurate shape the ceramic parts have to be covered with a stencil; each article to be metallised requires, consequently, a sheet-metal frame. If a great number of ceramic parts are to be metallised by this method a great number of stencils will be required, which must fit very tightly in order to avoid irregular borders. The thickness of the metal layer created by this method is dependent on the distance of the article from the cathode. Plain surfaces can be coated relatively easily. If the surface, however, has projections or recesses which have to be included in the silvered area the thickness of the deposit will be larger on the projections than in the recesses.

The adherence of this type of metal coatings is not very great as no chemical reaction between ceramic and metal coating takes place. The contact of the coating with the ceramic surface is nevertheless very intimate and for this reason this method is very often used in the preparation of specimens for accurate physical measurements.

Purely thermal vaporisation is very similar to cathode sputtering. While in the case of cathode volatilisation the heated cathode wire emits vapour under the effect of glow discharge, in the latter process the metal is melted in a crucible and vaporised in vacuo. The properties of layers thus produced do not differ from those produced by cathode sputtering.

A further metallising process is the formation of a deposit of silver by reduction of silver-salts in dilute solution. This process is used to a very great extent in silvering the inside of double-walled glass vessels, such as heat-insulating Thermos or Dewar flasks. The silver coating produced by this process does not form any

chemical combination with the surface and consequently does not adhere very firmly. It is also rather difficult to obtain coatings of a definite and accurate shape; those parts of the surface which have not to be metallised must be protected by a stencil, varnish or other low-temperature melting substances which can subsequently be removed. The coating is very thin and even several repetitions of the process do not form coatings of sufficient thickness for subsequent soldering.

The processes described so far have one feature in common, *viz.*, no interaction takes place between metal and ceramic and, consequently, the metal coating does not adhere firmly to the surface. This drawback was a problem calling for solution when new ceramic low-loss materials for high-frequency purposes were being developed. Many of the favourable electrical and mechanical characteristics of these new materials could not have been fully utilised had it not been possible to produce firmly adherent metal coatings. The process which solved this problem was the burning of a silver preparation containing ceramic fluxes on to the ceramic. This process is derived from the decoration technique used in the manufacture of artistic and domestic pottery. Most ceramic colours are mixtures of metal oxides with ceramic fluxes. The mixtures are finely ground and the resulting powder is held in suspension in oil and turpentine. It is applied to the ceramic article by various means, *e.g.*, by a brush and after drying subjected to a temperature of between 650° C. and 850° C., when the flux melts and dissolves the colouring metal oxide. For instance, to obtain a blue colour cobalt oxide is added to the flux, for green ceramic colours chrome oxide, for brown iron oxide, for pink tin-chromium compounds, etc. Such colours are silicates or borates of various metal oxides and are non-conductive. Oxides of gold and silver differ from non-precious metal oxides by the fact that (owing to the lesser affinity of precious metals to oxygen) they are reduced when subjected to the firing process. Precious metal colours of this type were first used at the beginning of the 19th century; they were prepared by dissolving gold chloride in sulphurised oils or balsam resins. The solution is diluted with light oils such as turpentine; bismuth-nitrate which acts as a flux is often added. This type of gold paint does

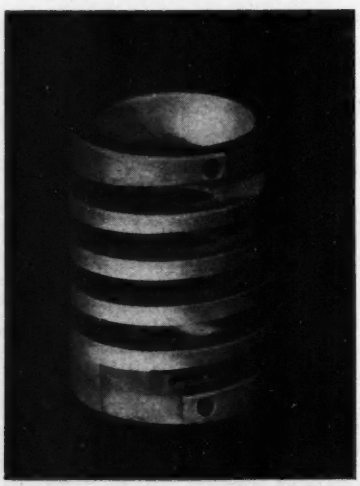
Fig. 2. Silvered ceramic high-voltage capacitor part.

not adhere as firmly to the ceramic surface as other types of ceramic colours containing more active fluxes, but for decorating domestic pottery it fulfils its purpose, producing, after firing, a very shiny and brilliant appearance.

For coating ceramics for high-frequency purposes the precious metal paints used in the decorated pottery art are modified by the addition of more powerful fluxes such as have been used previously with other ceramic colours like blue, green, etc.

Compounds now in general use for silvering ceramic ware comprise

Fig. 3. Silvered ceramic coil.



silver oxide or organic combinations of silver, or finely powdered silver in a mixture of resins, ceramic fluxes, such as lead borates, lead silicates and sodium borates. Oils and other diluting agents impart to the paint the property of quick drying. At about 400° C. the silver oxide of the preparation is reduced and metallic silver is formed; the coating turns from the black of the silver oxide into the white of the silver. The temperature required to complete the firing is dependent on the nature of the flux used in the preparation of the paint and on the nature of the ceramic. The maximum permissible temperature is 950° C. when the melting point of the silver is reached. The lower the melting point of the flux the lower the temperature which has to be applied. The surface of the ceramic articles also has a certain influence on the most suitable firing temperature; glazed ceramic articles for instance require a lower firing temperature than unglazed articles. The adhesion of the metal coating to the ceramic surface is caused by interaction between the flux and the metallic particles. The silver particles are very evenly distributed over the whole ceramic surface and cemented together by the flux. It is obvious that a ratio of flux to silver must be chosen which will not greatly reduce the conductivity of the silver coating, *i.e.*, not too much flux must be used in the preparation of the paint. A silver coating produced by this method is by no means such a homogeneous metal skin as that produced by rolling on a soft metal foil; for instance the electrical conductivity of a ceramic silver coating having a certain thickness has only half the conductivity of a homogeneous silver foil of the same cross-section and length.

The thickness of the layer may be increased by repeated coatings or by plating with silver or copper to facilitate subsequent soldering operations. The depth may also be increased by the Schoop spraying process. When increasing the thickness by galvano-plating it must be borne in mind that the fluxes used in the preparation of the paint are not completely acid-resistant, metal-salt solutions which during the galvano-plating process would attack the fluxes have to be avoided. A method of increasing the silver coating is by plating the ground layer first with copper and then by covering the copper layer

(*Continued on page 262.*)

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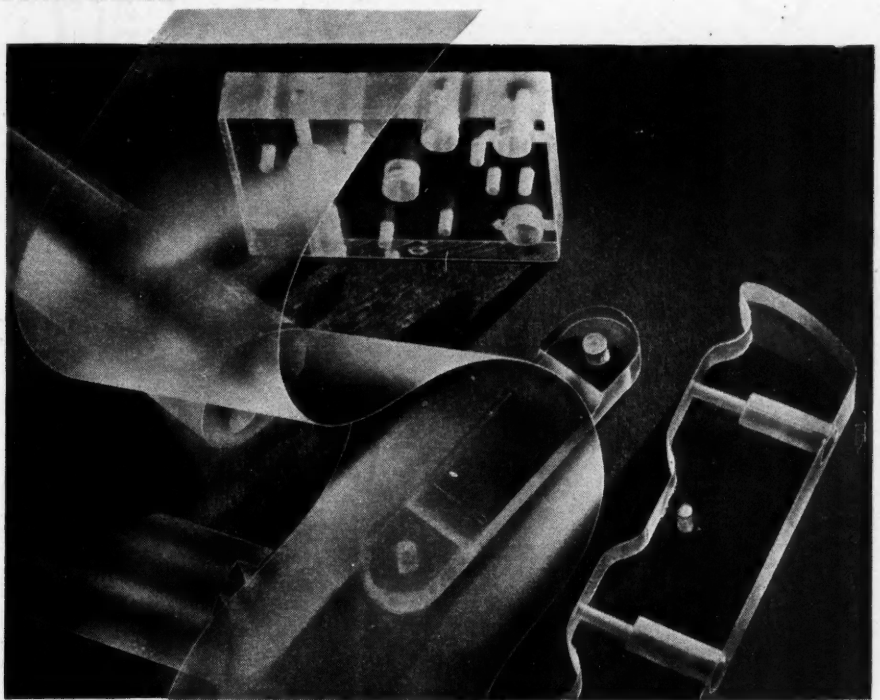
first RADAR



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DISTRENE Regd. (Polystyrene) was the material that completely met these needs.

Now, in the change over from war to peace, you have your problems of high-frequency radio and electrical insulation. DISTRENE FOIL can help you to surmount them.

In DISTRENE FOIL (Orientated Polystyrene Film) the molecules are specially arranged during manipulation so that the tensile strength is increased by 3 times and the flexibility by 10 times.

Power Factor
0·0002 - 0·0004

Tensile Strength
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Thickness
0·001" to 0·008"

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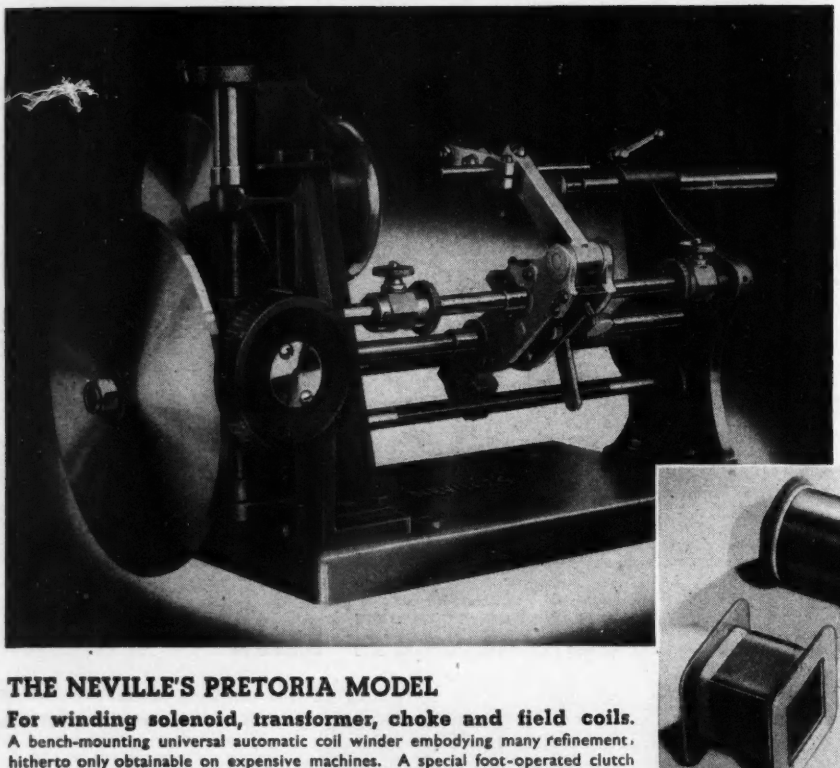
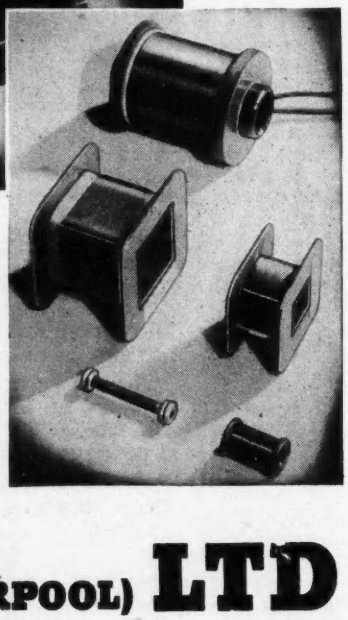
Coil winding MACHINES



A typical selection of coils wound on the Neville's Pretoria Coil Winding Machine.



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A bench-mounting universal automatic coil winder embodying many refinements hitherto only obtainable on expensive machines. A special foot-operated clutch gives smooth control of the winding spindle and it is possible to wind up to four coils simultaneously.

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DIMENSIONS : The machine is 23½" long, 10" wide and 12" high.
DRIVE : 1/4 H.P., 1425 R.P.M. Electric Motor.
SPINDLE SPEEDS : 400, 530, 800, 1250, 3000, R.P.M.
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3

Complex Waveforms

Analysis of Complex Waves (Concluded)

By HILARY MOSS, Ph.D., A.M.I.E.E.

Case (b).—Waves of Frequency Ratio tending to Unity—"Beats" (continued).

Continuing from the June issue we now consider the more general beat wave formed by the addition of two sinusoids of *unequal* amplitude. As compared with the simpler case where the amplitudes are equal, we note that:

(1) The "beat" period is unchanged and equal to $2.\pi/\delta\omega$.

(2) The period of the component wave is no longer $t=2.\pi/\left(\omega+\frac{\delta\omega}{2}\right)$ but tends to be nearer that of the component of major amplitude.

(3) The beat wave no longer lies within the double envelope

$$f(t) = \pm\ 2.B\cos\left(\frac{\delta\omega}{2}.\ t - \frac{\phi}{2}\right)$$

but instead lies within an *approximately* sinusoidal envelope, the amplitude of which varies between $A + B$ and $A - B$ $(A > B)$ where A and B are the component wave amplitudes.

Determination of the Envelope of the General Beat Wave

As before, let the two component waves be denoted by $A\sin\omega t$ and $B\sin(\omega+\delta\omega).t$, and let these terms be represented by the vectors $\vec{OA}$ and $\vec{OB}$ in Fig. 6. The angle between these vectors changes continuously as they rotate. The resultant beat wave is the vector sum of $\vec{OA}$ and $\vec{OB}$, and is thus equal to $\vec{OC}$ in Fig. 6. However, in this case we are not interested in the *phase* of the resultant, but only in its magnitude. By simple trigonometry we may write:

$$|OC|^2 = |OA|^2 + |OB|^2 + 2|OA||OB|\cos A\hat{O}B$$

so that the beat envelope has an amplitude of

$$OC = \sqrt{A^2 + B^2 + 2.A.B.\cos(\delta\omega)t} \quad (56)$$

This last expression reveals a periodicity of $2.\pi/\delta\omega$ regardless of the relative amplitudes of the components, thus justifying (1) above. In addition, Equation (56) shows that the edge of the beat envelope is not a pure sine curve. The extent of the departure from a purely sinusoidal shape depends on the relative amplitudes of the components A and B. To investigate this point, let $A/B = k$, where we suppose that $B > A$ so that $k < 1$. Then (56) may be expressed

$$OC = B\sqrt{1 + k^2 + 2.k\cos(\delta\omega)t}$$

which can be rearranged in a form suitable for binomial expansion

$$OC = B.\sqrt{\left\{\frac{1 + k^2}{2}\right\} + k\cos(\delta\omega)t} \qquad k<1$$

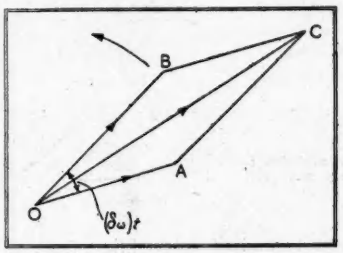


Fig. 6.

Expanding by the binomial theorem, and then expanding the powers of $\cos(\delta\omega)t$ in terms of multiple angles, finally gives, after some rearrangement,

$$OC = B\left[\sqrt{(1 + k^2)} - \frac{k^2}{4(1 + k^2)^2} + \left\{\frac{k}{\sqrt{(1 + k^2)}} + \frac{3.k^3}{8(1 + k^2)^{5/2}}\right\}\cos(\delta\omega)t - \frac{k^2}{4(1 + k^2)^{3/2}}\cos 2(\delta\omega)t + \frac{k^3}{8(1 + k^2)^{5/2}}\cos 3(\delta\omega)t - \ldots\right] \quad (57)$$

in which expression all powers of $k.\cos(\delta\omega)t$ above the third have been neglected. (57) then holds for only small values of k, say $k < \frac{1}{4}$. From it we obtain the following results for the harmonic components in the beat envelope:

Fractional second harmonic component compared to fundamental $= \frac{k}{4(1 + k^2)}$ (neglecting k^3 against k)

Fractional third harmonic component $= \frac{k^2}{8(1 + k^2)^2}$

Notice that both these expressions tend steadily to zero as $k \to 0$, so that an almost "pure" envelope is obtainable by mixing two waves with very large difference in amplitude. This result is of importance in connexion with the design of beat frequency oscillators.

Owing to the restriction on the value of k imposed by the approximate expansion (57) we cannot use the results to deduce the maximum amount of harmonic distortion present in the beat, which will obviously occur when $k = 1$. However, it was shown in the June issue that when two sine waves of equal amplitude ($k = 1$) are compounded, the beat envelope is like a full wave rectified sine curve. The harmonic analysis of this curve is given in the table, Case *j*, and shows that the second harmonic distortion is 20 per cent., and the third harmonic distortion about 8.5 per cent., of the fundamental. These are therefore the maximum distortions which can arise.

Fig. 7 illustrates a typical beat wave formed by the summation of the two terms $2\cos 6t$ and $\cos 7t$, together with the envelope which has been sketched in. Change of the relative phases of the two component waves merely moves the position of the resultant wave within the envelope, but has no effect on the envelope itself. (Compare Photos 171 and 169.)

Since the maximum value of $\cos(\delta\omega)t$ is $+1$, and its minimum value -1, it follows from (56) that the envelope amplitude fluctuates between the values $A + B$ and $A - B$, as indicated. The position of minimum envelope amplitude will be termed the "waist," and that of maximum envelope amplitude the "bulge." The measurement of these two quantities immediately defines the component amplitudes A and B.

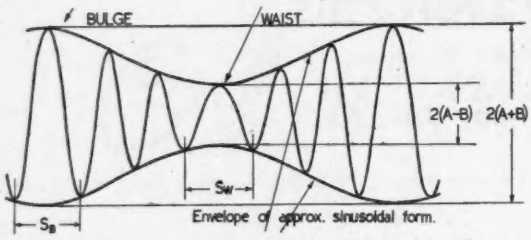


Fig. 7. Beat wave formed by addition of 2cos6t and cos7t.

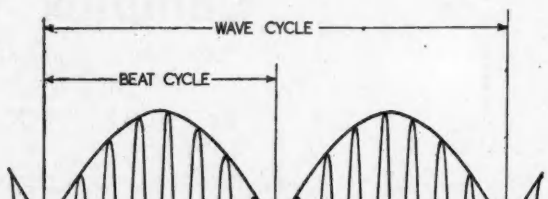


Fig. 8. Beat wave formed by addition of sin5t and sin5½t illustrating difference between *cycle* frequency and *beat* frequency.

Determination of the Frequencies of the Two Components

Suppose that to the wave

$$f(t) = A\sin\omega t$$

we add the wave

$$f(t) = k.A\sin(\omega + \delta\omega)t$$

Consider the resultant wave as k grows steadily from zero to some value many times unity. It has been shown that the beat frequency is defined by $t = 2.\pi/\delta\omega$ regardless of the wave amplitudes or phases, so that the growth of k has no effect on the beat period. Now when $k << 1$ it is clear that the frequency of the waves in the beat must tend to $\omega/2.\pi$, and when $k >> 1$ they must tend to $(\omega + \delta\omega)/2.\pi$. It was also proved in the June issue that when $k = 1$, the frequency of the wave forming the beat is $(\omega + \delta\omega)/2.\pi$, *i.e.*, is the mean of the component waves. Hence, as k increases the frequency of the wave in the beat must increase continuously from $\omega/2.\pi$ to $(\omega + \delta\omega)2/.\pi$. The process of frequency increase is well illustrated in Photos Nos. 166 to 170, which show the gradual appearance of an "extra" wave peak as the amplitude of the component of higher frequency increases.

Now consider the two groups of beat waves defined by:

$$f(t) = A\sin\omega t + k.A\sin(\omega + \delta\omega)t$$

where $k << 1$

$$f(t) = A\sin\omega t + k.A\sin(\omega - \delta\omega)t$$

Both these systems have component frequencies tending to that of the component of major amplitude, *i.e.*, a frequency tending to $\omega/2.\pi$, and both will have the same beat frequency of $\delta\omega/2.\pi$ (equal to the difference of the component frequencies). Yet the frequency of the component of minor amplitude is in the first case greater, and in the second case less, than that of the major component. Is there any way of resolving the ambiguity and of determining from the resultant waveforms which system has the smaller amplitude component of higher frequency?

The following rule is given by Manley* in his book:

(a) If the minor component is of *higher* frequency than the major, the distance between successive peaks at the bulge (S_B), is *less* than the corresponding distance at the waist (S_W).

(b) If the minor component is of *lower* frequency than the major, the distance between successive peaks at the bulge is *greater* than the corresponding distance at the waist.

This interesting result is readily established for the special case where the beat wave is symmetrical about the bulge and the waist, as is the case in the example of Fig. 7. There would seem no reason to doubt the generality of the results for all phase angles between the component waves. In this case the phrase "distance between successive peaks" would be interpreted as meaning the maximum or minimum distances in the *region* of the bulge or waist.

Beat Waveform in Relation to Complex Wave Theory

It is desirable to recognise the simple beat wave in the case where $\omega/\delta\omega$ is integral, as a special case of a complex wave in which the only Fourier terms present are two *adjacent* harmonics of fairly high order. If the two components have angular frequencies of ω and $\omega + \delta\omega$, then the adjacent components are of effective frequency $\omega/\delta\omega$ and $\omega/\delta\omega + 1$, where the complete wave period (and in this case also the beat period) is $t = 2.\pi$. The case where $\omega/\delta\omega$ is non-integral is treated below.

It is important to appreciate that in a similar way several common types of complex wave may be considered as belonging to a Fourier series in which the fundamental and/or early terms are of zero or negligible amplitude. Some simple examples of suppression of the fundamental are shown in Photos Nos. 154 to 165. A more complicated special case, of common occurrence in wireless, is that of the exponentially damped sinusoidal wave pulse, which is treated in a later section.

Beats Formed by Waves in which $\omega/\delta\omega$ is Non-integral

A study of Equations (55) and (55a), June issue, shows that the period of the actual beat remains $t = 2\pi/\delta\omega$. This is otherwise apparent from Equation (56). Successive beat envelopes, however, do not contain identical waveforms. This is illustrated in Fig. 8, in which curve the components are $\sin 5t$ and $\sin 5\frac{1}{2}t$. In this particular case the complete *wave* cycle embraces two beat cycles.

A little consideration will establish the following principle:

"The number of beat waves contained in one complete wave cycle is N, where N is the smallest integer which makes $N.\omega/\delta\omega$ integral."

As a corollary we note that if $\omega/\delta\omega$ is irrational, then no two beat envelopes in the resultant wave train are identical in content, and the wave period is infinite.

Thinking along the lines indicated in the last section, it will be appreciated that a beat wave in which $\omega/\delta\omega$ is made integral by multiplication by N, belongs to a Fourier series containing only two components separated by $N - 1$ terms. This conception is of practical value. For example, it tells us that to display the beat system indicated in Fig. 8 we should combine the frequencies 15θ and 17θ.

* "Waveform Analysis," Chapman and Hall.

In the case where $\omega/\delta\omega$ is irrational we cannot regard the complex wave as belonging to any Fourier series, as the wave period is infinite.

Symmetry Theory and Beat Waveforms

The beat waves under consideration have for the most part been represented by Equation (55), *i.e.*:

$$f(t)=A\sin(\omega t+\phi)+B\sin(\omega+\delta\omega).t \quad (55)$$

From this equation it follows immediately that provided *only* $\phi = 0$, and regardless of the values of A and B, or whether $\omega/\delta\omega$ is integral, the resultant wave system must be skew symmetrical about the origin $t = 0$, and therefore also skew symmetrical about the point of commencement of any wave cycle. The wave system will also be skew-symmetric about every waist in the case where $\omega/\delta\omega$ is integral.

If, on the other hand, the beat is represented by the sum of two cosine terms as is the waveform of Fig. 7, then the system must possess normal symmetry about the origin.

General Method of Harmonic Analysis

It is proved in the standard texts that in Equation (45), *i.e.*:

$$f(\theta) = \tfrac{1}{2}a_0 + \sum a_k\cos k\theta + b_k.\sin k\theta \quad (45)$$

$$a_k = \frac{1}{\pi}\int_0^{2\pi} f(\theta)\cos k\theta d\theta \quad \ldots\ldots (58)$$

$$b_k = \frac{1}{\pi}\int_0^{2\pi} f(\theta)\sin k\theta d\theta \quad \ldots\ldots (59)$$

$$a_0 = \frac{1}{\pi}\int_0^{2\pi} f(\theta) d\theta \quad \ldots\ldots (60)$$

These results permit the coefficients of the Fourier expansion of any given wave to be determined. If the curve is of arbitrary shape, such as might be obtained experimentally from some form of oscillograph, and such that its complete wave cycle cannot readily be divided into portions capable of analytic expression, then the approximate values of

$$\int_0^{2\pi} f(\theta) \begin{matrix}\cos\\ \sin\end{matrix} k\theta d\theta$$

may be obtained by measurements on a large number of equally spaced ordinates. On the other hand, many curves can be divided into portions, each capable of analytic expression, and the value of $\int_0^{2\pi} f(\theta) \begin{matrix}\cos\\ \sin\end{matrix} k\theta d\theta$ throughout the complete cycle may then be found by summation of the separate contributions of each portion of the cycle. Thus, if $\phi(\theta)$, $\psi(\theta)$ . . . $\mu(\theta)$ represent the analytic expressions for portions of the complete cycle between 0 and α, α and β . . . λ and 2π respectively, then:

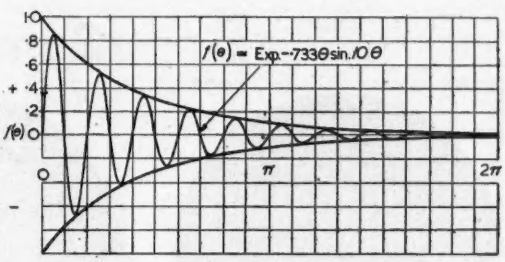


Fig. 9(a). Damped sinusoidal pulse.

$$\int_0^{2\pi} f(\theta) \begin{matrix}\cos\\ \sin\end{matrix} k\theta d\theta = \int_0^{\alpha} \phi(\theta) \begin{matrix}\cos\\ \sin\end{matrix} k\theta d\theta + \int_{\alpha}^{\beta} \psi(\theta) \begin{matrix}\cos\\ \sin\end{matrix} k\theta d\theta + \ldots$$

$$\ldots + \int_{\lambda}^{2\pi} \mu(\theta) \begin{matrix}\cos\\ \sin\end{matrix} k\theta d\theta \ldots\ldots\ldots\ldots (61)$$

The great majority of the results shown in the table on page 248 were obtained in this manner.

The fullest use must always be made of the symmetry deductions as treated in the April issue. For example, if a wave is alternate as is the wave of Case *g*, then:

$$\int_0^{\pi} f(\theta)\sin k\theta d\theta = \int_{\pi}^{2\pi} f(\theta)\sin k\theta d\theta$$

so that in this case

$$b_k = \frac{2}{\pi}\int_0^{\pi} f(\theta)\sin k\theta d\theta \quad \ldots\ldots (59a)$$

which involves only half the working of the more general (59). Similarly, in an alternant wave the coefficients of the cosine terms are given by:

$$a_k = \frac{2}{\pi}\int_0^{\pi} f(\theta)\cos k\theta d\theta \quad \ldots\ldots (58a)$$

In analysing a wave one naturally chooses the origin of co-ordinates in the manner necessary to make any symmetries (normal or skew) appear about such origin. If, for some special reason, the final result is required to refer to an origin in some other position on the wave cycle, it is still advisable to compute the Fourier series with the origin placed in the best position so far as the symmetries are concerned, and to transform the *final* result by shift of reference axes.

It will be seen from Equation (60) that $a_0/2$ is equal to the separation between the horizontal reference axis and the mean curve height. It may therefore be made zero by choice of horizontal axis so that the areas of the curve above and below this axis are equal.

Example of Harmonic Analysis—Damped Sinusoidal Oscillation.

In illustration of these principles we now analyse into its Fourier components the damped sinusoidal oscillation illustrated in Photo. No. 88 (January, 1945, issue). This curve belongs to the class capable of analytic expression—in this case over the whole of its cycle, so that it is unnecessary to use Result (61).

The curve may be represented by

$$f(\theta) = \exp.-a\theta.\sin b\theta \quad \ldots\ldots (62)$$

and is drawn to scale for the special case where $A = 1$, $a = 0.733$, and $b = 10$ in Fig. 9(a). The value $a = 0.733$ appears peculiar at first sight, but will be found to make the amplitude of the wave group fall to 1/100 of its initial value in the interval 2π. Only one cycle of the wave is drawn, but it is, of course, assumed that the complete wave train consists of an infinite number of such cycles since none of the principles here treated is applicable to non-repetitive phenomenon.

The wave possesses no form of symmetry, but is clearly approximately balanced about the X axis, so that the areas of the curve on either side of this line are approximately equal, and in consequence the constant term a_0 will be nearly zero. Its actual value is of no special interest.

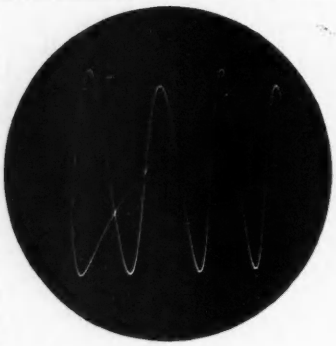
Substituting from (62) into (58) gives

$$a_k = \frac{1}{\pi}\int_0^{2\pi} \exp.-a\theta.\sin b\theta\cos k\theta d\theta$$

Writing $\sin b\theta\cos k\theta$ as the difference between two sine terms enables this equation to be expressed as the difference of two standard form integrals

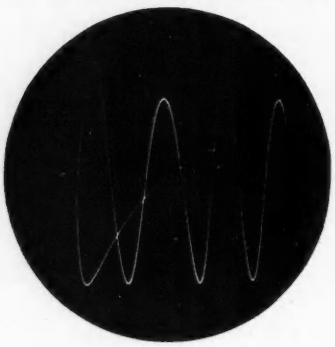
(*Continued on page 250.*)

Complex Waveforms with



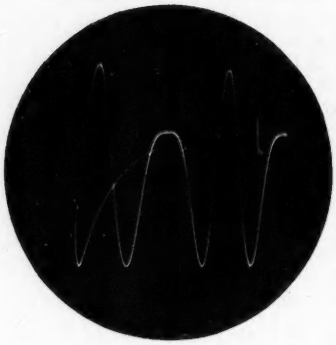
154

$$A \sin 2\theta + \frac{A}{10} \sin\left(3\theta + \frac{\pi}{6}\right)$$



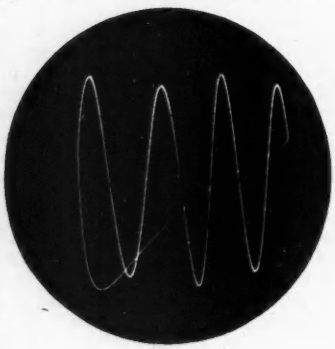
155

$$A \sin 2\theta + \frac{A}{5} \sin\left(3\theta + \frac{\pi}{6}\right)$$



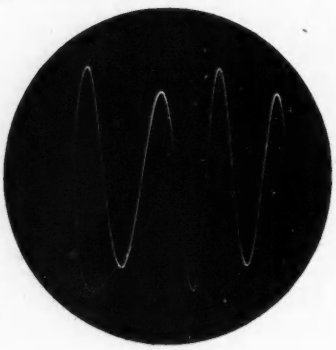
156

$$A \sin 2\theta + \frac{2}{5} A \sin\left(3\theta + \frac{\pi}{6}\right)$$



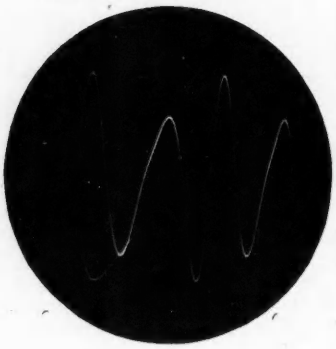
157

$$A \sin 2\theta + \frac{A}{10} \sin\left(3\theta + \pi\right)$$



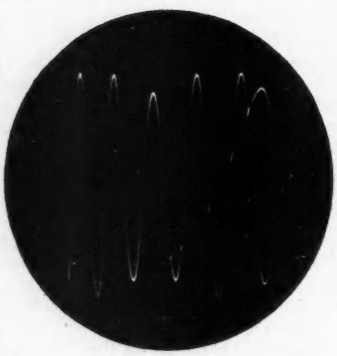
158

$$A \sin 2\theta + \frac{A}{5} \sin\left(3\theta + \pi\right)$$



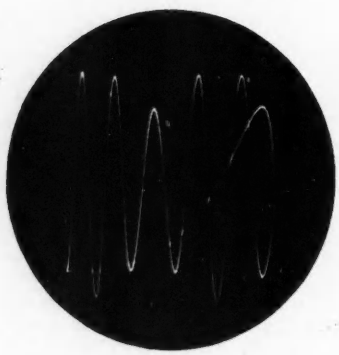
159

$$A \sin 2\theta + \frac{2}{5} A \sin\left(3\theta + \pi\right)$$



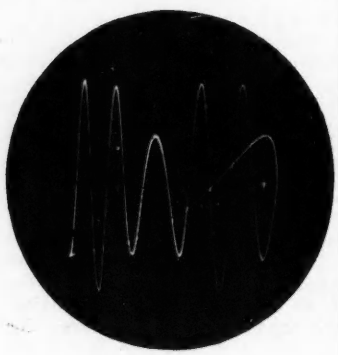
160

$$A \sin 3\theta + \frac{A}{10} \sin\left(4\theta - 67.5^\circ\right)$$



161

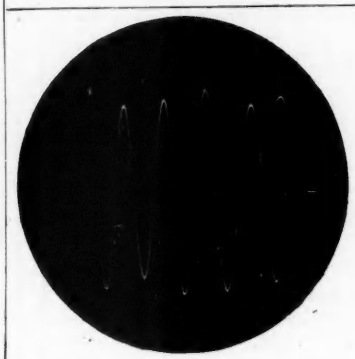
$$A \sin 3\theta + \frac{A}{5} \sin\left(4\theta - 67.5^\circ\right)$$



162

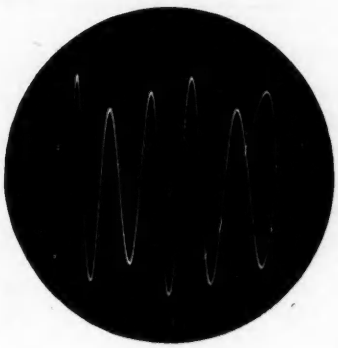
$$A \sin 3\theta + \frac{2}{5} A \sin\left(4\theta - 67.5^\circ\right)$$

no Fundamental Component



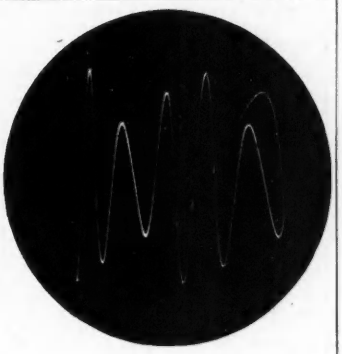
163

$A \sin 3\theta + \frac{A}{10} \sin 4\theta$



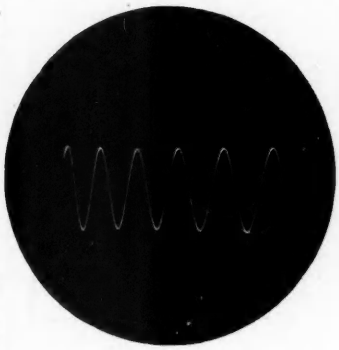
164

$A \sin 3\theta + \frac{A}{5} \sin 4\theta$



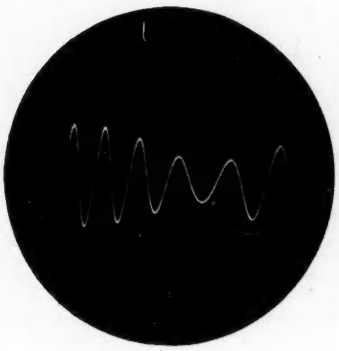
165

$A \sin 3\theta + \frac{2}{5} A \sin 4\theta$



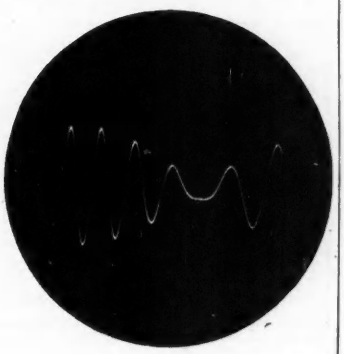
166

$A \sin 6\theta$



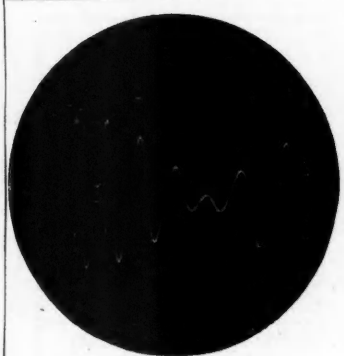
167

$A \sin 6\theta + \frac{2}{5} A \sin \left(7\theta + \alpha\right)$



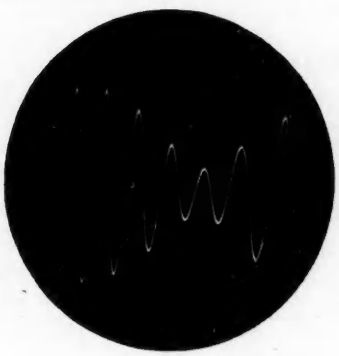
168

$A \sin 6\theta + \frac{3}{5} A \sin \left(7\theta + \alpha\right)$



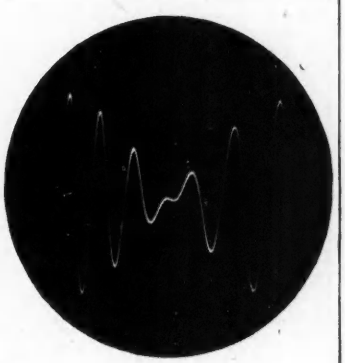
169

$A \sin 6\theta + A \sin (7\theta + \alpha$



170

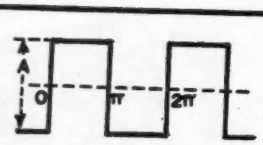
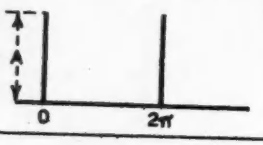
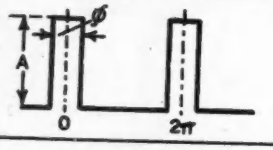
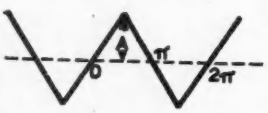
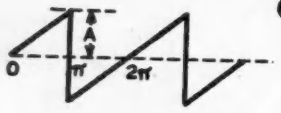
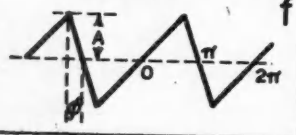
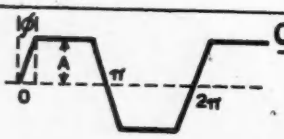
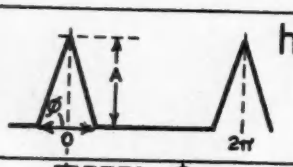
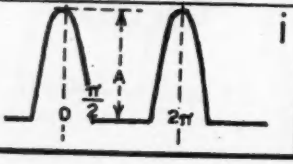
$A \sin 6\theta + \frac{3}{2} A \sin \left(7\theta + \alpha\right)$



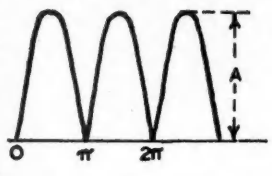
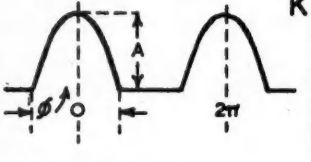
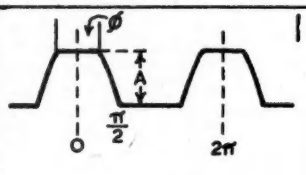
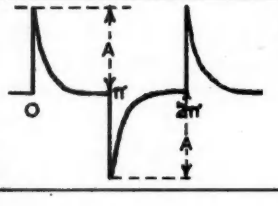
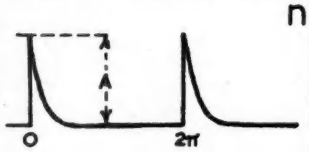
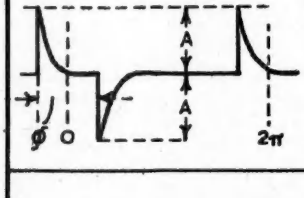
171

$A \sin 6\theta + A \sin (7\theta + \beta)$

Table: Expressions for

a 	Square Wave, Mark/space ratio unity.	$f(\theta)=\frac{2A}{\pi}\sum_{k=1}^{k=\infty}\frac{\sin(2k-1)\theta}{(2k-1)}$
b 	Infinitely short pulse	$f(\theta)=\frac{A\phi}{2\pi}+A\sum_{k=1}^{k=\infty}\frac{\phi}{\pi}\cos k\theta$ where $\phi\to 0$ but $A\phi$ remains finite
c 	Short square wave, duration ϕ	$f(\theta)=\frac{A\phi}{2\pi}+\frac{2A}{\pi}\sum_{k=1}^{k=\infty}\frac{1}{k}\sin\frac{k\phi}{2}\cos k\theta$
d 	Uniform triangular wave	$f(\theta)=\frac{8A}{\pi^2}\sum_{k=1}^{k=\infty}(-1)^{k+1}\frac{1}{(2k-1)^2}\sin(2k-1)\theta$
e 	Sawtooth wave with infinitely short flyback	$f(\theta)=\frac{2A}{\pi}\sum_{k=1}^{k=\infty}(-1)^{k+1}\frac{1}{k}\sin k\theta$
f 	General sawtooth wave.	$f(\theta)=\frac{2A}{\phi(\pi-\phi)}\sum_{k=1}^{k=\infty}(-1)^{k+1}\frac{1}{k^2}\sin k\phi.\sin k\theta$
g 	Trapezoidal wave	$f(\theta)=\frac{4A}{\pi\phi}\sum_{k=1}^{k=\infty}\frac{1}{(2k-1)^2}\sin(2k-1)\phi.\sin(2k-1)\theta$
h 	Triangular pulse	$f(\theta)=\frac{A\phi}{4\pi}+A\sum_{k=1}^{k=\infty}\left\{\frac{2}{k\pi}\sin\frac{k\phi}{2}-\frac{4}{k^2\pi\phi}\left(\frac{k\phi}{2}\sin\frac{k\phi}{2}-2\sin^2\frac{k\phi}{4}\right)\right\}\cos k\theta$
i 	Rectified sine wave (half-wave)	$f(\theta)=\frac{A}{\pi}+\frac{A}{2}\cos\theta+\frac{2A}{\pi}\sum_{k=1}^{k=\infty}(-1)^{k+1}\frac{1}{4k^2-1}\cos 2k\theta$

Complex Waveforms

j 	Rectified sine wave (full wave)	$f(\theta)=\frac{2A}{\pi}-\frac{4A}{\pi}\sum_{k=1}^{k=\infty}\frac{1}{(4k^2-1)}\cos 2k\theta$
k 	Tip of sine wave, duration ϕ	$f(\theta)=\frac{A}{\pi(1-\cos\phi/2)}\left(\sin\frac{\phi}{2}-\frac{\phi}{2}\cos\frac{\phi}{2}\right)+\frac{A}{\pi(1-\cos\phi/2)}\sum_{k=1}^{k=\infty}\left\{\frac{\sin(k+1)\frac{\phi}{2}}{k+1}+\frac{\sin(k-1)\frac{\phi}{2}}{k-1}-\frac{2}{k}\sin k\frac{\phi}{2}\cos\frac{\phi}{2}\right\}\cos k\theta$
l 	Chopped sine wave	$f(\theta)=\frac{A\phi}{2\pi}+\frac{A}{\pi}\left(1-\sin\frac{\phi}{2}\right)+\left\{\frac{A}{2}+\frac{2A}{\pi}\sin\frac{\phi}{2}\right\}\cos\theta+\frac{2A}{\pi}\sum_{k=2}^{k=\infty}\left\{\frac{\sin k\frac{\phi}{2}}{k}+\frac{\cos k\frac{\pi}{2}}{1-k^2}-\frac{\sin(1-k)\frac{\phi}{2}}{2(1-k)}-\frac{\sin(1+k)\frac{\phi}{2}}{2(1+k)}\right\}\cos k\theta$
m 	Differentiated square wave of unity mark-space ratio as (a)	$f(\theta)=\frac{2AT}{\pi}\sum_{k=1}^{k=\infty}\frac{1}{1+T^2(2k-1)^2}\left\{T(2k-1)\sin(2k-1)\theta+\cos(2k-1)\theta\right\}$ where $T=2\pi f.CR$ in which C & R are the capacitance and resistance of the short time-constant circuit involved. f=frequency
n 	As (m), but negative half-cycle suppressed	$f(\theta)=\frac{TA}{2\pi}+\frac{TA}{\pi}\sum_{k=1}^{k=\infty}\frac{1}{(1+T^2k^2)}\left\{Tk.\sin k\theta+\cos k\theta\right\}$ where T is defined as in (m) above.
o 	Differentiated square wave of unequal mark-space ratio as (c)	$f(\theta)=\frac{2AT}{\pi}\sum_{k=1}^{k=\infty}\frac{1}{(1+T^2k^2)}\sin\frac{k\phi}{2}\left\{Tk.\cos k\theta-\sin k\theta\right\}$ where T is defined as in (m) above.

NOTE that in (m), (n) and (o) the Fourier expansions hold only if the time constants are so short that the transients decay substantially to zero in the interval between the pulses.

$$a_k = \frac{1}{2.\pi}\int_0^{2\pi} \text{exp.}-a\theta.\sin(k+b)\theta d\theta - \frac{1}{2.\pi}\int_0^{2\pi} \text{exp.}-a\theta.\sin(k-b)\theta d\theta$$

whence

$$a_k = -\frac{1}{2.\pi}\left[\frac{\text{exp.}-a\theta}{a^2+(k+b)^2}\left\{a\sin(k+b)\theta + (k+b)\cos(k+b)\theta\right\}\right]_0^{2.\pi}$$

$$+\frac{1}{2.\pi}\left[\frac{\text{exp.}-a\theta}{a^2+(k-b)^2}\left\{a\sin(k-b)\theta + (k-b)\cos(k-b)\theta\right\}\right]_0^{2.\pi}$$

The general solution of this definite integral is very cumbersome. However, in the complex wave we are considering, the result of inserting the upper limit of integration, $2.\pi$, is to give negligible amplitude (1/100) of that at the commencement of the cycle. Thus, exp.$-a.2.\pi$ may be regarded as zero, and with this approximation, after some reduction there results:

$$a_k = \frac{b(a^2+b^2-k^2)}{\pi\left\{a^2+(k+b)^2\right\}\left\{a^2+(b-k)^2\right\}} \quad \ldots\ldots\ldots (63)$$

By similar working, and again assuming that exp.$-2\pi a = 0$ we find

$$b_k = \frac{2.b.k.a}{\pi\left\{a^2+(k+b)^2\right\}\left\{a^2+(b-k)^2\right\}} \quad \ldots (64)$$

(63) and (64) then define the relative amplitudes of the Fourier components, but it will be noted that they hold only when the damping is sufficiently high to cause the wave train to decay substantially to zero in the interval between the successive groups. They would not be a good approximation, for example, for the damped wave train shown in Photo. No. 89.

Fig. 9(b) shows the components of the wave of Fig. 9(a), as found by use of (63) and (64). As would be expected, the major component of the Fourier series is a sine term of the same frequency as the contents of the damped envelope. The cosine terms appear to have a somewhat wider spectrum, and there are appreciable components in the range between half and twice the predominant frequency. Examination of (64) shows that provided $a << (b+k)$, then the frequency spectrum of the sine terms increases as a increases, *i.e.*, as the damping increases. This is to be expected. The same effect is responsible for the increased bandwidth of a parallel resonant circuit, as its damping is increased, *i.e.*, as its Q decreases.

Notes on the Production of some of the Waves shown in Table

(1) *Damped Sinusoidal Pulse.*

This may be conveniently generated by utilising the "ringing" properties of a resonant circuit connected in the anode of a valve. The resonant circuit may be regarded as an inductance L shunted by capacity C, and the losses in the circuit, which cause the damping, may be regarded as due to an equivalent resistance R in series with the inductance. Normally, the valve is conducting, with standing current I, so that the energy stored in the inductance is $\frac{1}{2}L.I^2$. If the valve is suddenly cut off by means of a long negative pulse applied to its grid, it can be shown that provided the resistance R is not too large, the resonant network will execute a damped sinusoidal oscillation, as the initially stored energy in the inductance is periodically transferred to the condenser and back again. The amplitude of these surges dies away as their energy is dissipated in the resistance. If the damping is small, then the first maximum voltage peak developed across the condenser will be given by $\frac{1}{2}L.I^2 = \frac{1}{2}C.V^2$ approx., so that $V = I\sqrt{\frac{L}{C}}$

An approximate expression for the condenser voltage after any time t can be shown to be:

$$e = I\sqrt{\frac{L}{C}}\ \text{exp.}\frac{R}{2.L}.t\ \sin\frac{1}{\sqrt{L.C}}.t \quad (65)$$

provided that the damping is not excessive. (65) would be reasonably applicable to the wave of Fig. 9(a). It has, of course, precisely the same form as (62).

(2) *Tip of Sine Wave (Case k).*

This is conveniently generated by the biased-back valve method, in which a large negative standing bias is applied to the grid in series with a sine wave of comparable amplitude. The actual value of the negative grid bias is adjusted until the valve conducts only on the positive tip of the input sine wave. This arrangement will be recognised in more familiar guise as a Class C amplifier. The standing grid bias may be obtained either by grid rectification or by separate battery. In the former method the grid is connected to the sine wave source via a condenser C, and to cathode via a resistance R. The product RC (time constant) is then made large compared to the cycle duration, so that on account of grid rectification the condenser C acquires a nearly constant negative potential approximately equal to the amplitude of the input signal. To obtain a sinusoidal wave tip of short duration in comparison with one half-cycle of the input sine wave, it is then necessary and sufficient that the input wave amplitude be many times the cut-off bias for the valve.

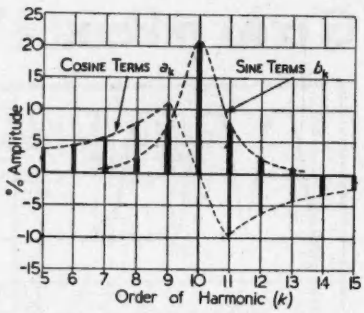


Fig. 9(b). Frequency spectrum of 9(a).

(3) *Chopped Sine Wave (Case l).*

This is best obtained by applying to the grid of a valve a large input sine wave, but preventing the grid from becoming appreciably positive, even although the mean grid potential is held nearly zero. This limiting may be done simply by insertion of a series resistance of large value between the grid and the source, and so preventing positive grid voltages of appreciable magnitude by flow of grid current, or alternatively, and preferably, by suppression of the positive half-cycle of the input wave with a diode. With a short grid-base valve and a large input signal, a reasonable approximation to a square wave may be thus obtained.

(4) *Exponential "Spikes" (Case m).*

These are produced by differentiation of a square wave by means of a short time constant resistance capacity series circuit. Spikes of only one sign (Case *n*) are obtained by suppression of the negative spike with a biased-back valve. (*See* Sept. issue, 1944.)

References

"Television Waveforms," C. E. Lockhart, ELECTRONIC ENGINEERING, June, 1942.

"Fourier Series and Transforms," M. M. Levy, *Journal Brit. I.R.E.*, May, 1946.

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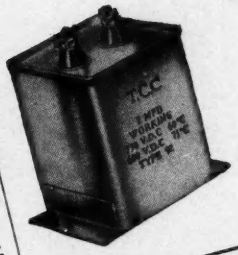
2.0	350	62	6/9	0.5	1,000	111	6/9
0.1	500	82	4/3	0.05	1,500	121 B	5/3
0.25	500	82	4/9	0.1	1,500	121 B	6/-
1.0	500	82	6/-	0.25	1,500	121 B	7/-
2.0	500	82	7/6	0.1	2,000	131	7/-
4.0	500	82	13/-	0.25	2,000	131	8/9
8.0	500	82	22/-	1.0	2,000	131	13/6
10.0	500	82	27/-	0.5	4,000	171 A	30/-



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0.25	350	CP.48.N	2/8	0.5	750	CP.90.S	3/10
0.5	350	CP.47.N	3/-	0.02	1,000	CP.45.U	1/10
1.0	350	CP.91.N	4/-	0.005	1,000	CP.45.W	1/10
0.05	500	CP.45.S	2/1	0.01	1,000	CP.45.W	1/10
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A Television Signal Generator

By R. G. HIBBERD, B.Sc., A.M.I.E.E.

Part 3.—R.F. Circuits and Monitors

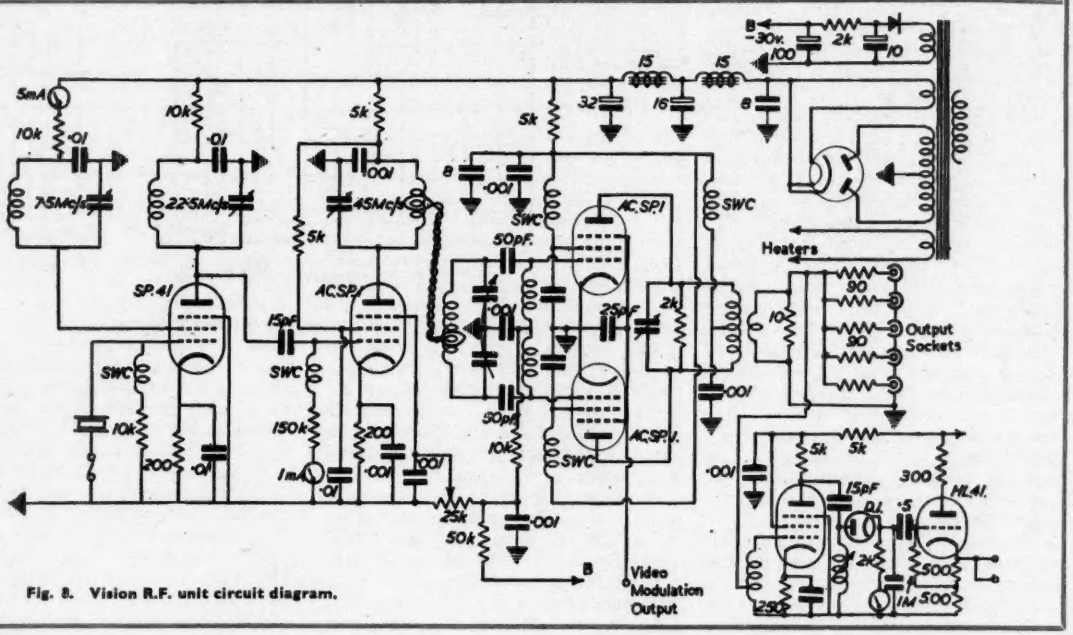


Fig. 8. Vision R.F. unit circuit diagram.

Vision R.F. Unit

THIS unit contains the radio-frequency circuits that produce the 45 Mc/s. carrier wave, together with the modulated amplifier and its output circuit. The complete circuit diagram is shown in Fig. 8. At the outset of the design, careful consideration was given to the method of producing the carrier wave, and it was eventually decided to use a 7·5 Mc/s. quartz crystal master oscillator, with subsequent frequency multiplication to give the required 45 Mc/s. signal. After preliminary work on methods of modulation, it was decided to use a push-pull modulated amplifier stage with suppressor grid modulation. This method gives a very low percentage of residual carrier and is very convenient for video modulation input.

Carrier Circuits

The screen-grid cathode circuit of an SP41 pentode is used as the master crystal oscillator circuit, at a frequency of 7·5 Mc/s. The resulting oscillation is electron coupled to the anode where an intermediate circuit tuned to 22·5 Mc/s. accepts the third harmonic. The output from this circuit is capacitatively coupled to the next stage, where the frequency is doubled to give the final carrier at 45 Mc/s. The coupling from the intermediate circuit is arranged to drive the doubler valve to pass a small grid current in order to distort the waveform and accentuate the second harmonic content. The grid current also serves as an indication for tuning the 22·5 Mc/s. circuit. The 45 Mc/s. output voltage appearing across the doubler valve anode circuit is varied by means of a negative voltage applied to the suppressor grid. The AC/SP1 valve was chosen for this stage on account of its suitable suppressor grid characteristic, cut off being obtained with about −12 volts.

Modulated Amplifier

The output from the doubler stage is link coupled to the push-pull modulated amplifier stage. Two AC/SP1 valves are used, with the video modulation applied to the suppressor grids in parallel. The symmetry of the push-pull grid circuit is maintained by using a split stator tuning condenser, with the rotor earthed. The valves are biased to operate under class B conditions. Since the final modulated carrier is developed across the anode circuit, the Q of this circuit must be chosen so that the required side-band transmission of 50 per cent. power at ± 2·5 Mc/s. is obtained. Accordingly, the circuit is damped with a 2,000-ohm resistance. The output is matched into a 10-ohm load resistance, the frequency response of the complete anode circuit being shown in Fig. 9. It will be seen that at ± 2·5 Mc/s. the voltage response is 76 per cent., which corresponds to a power response of 58 per cent. This is well within the specification of 50 per cent.

The two suppressor grids are modulated in parallel, the modulation characteristic being shown in Fig. 10. A modulating voltage of approximately 14 volts peak to peak is required, with black level at −7·5 volts. The synchronising impulses are limited by the valve characteristic, and in order to obtain the correct ratio of 30 per cent. sync. to 70 per cent. vision in the output, the modulating signal must have approximately 50 per cent. sync. to 50 per cent. vision. The residual carrier at the bottom of a synchronising impulse is about 2.5 per cent. of peak white.

The output signal developed across the 10-ohm resistance is fed to five

* B.T.H. Research Laboratory.

output sockets, each through a 90-ohm series resistance. This series resistance serves both as a padding resistance in series with the 10-ohm to match the 100-ohm cable, and also as a buffer resistance to isolate the output sockets from each other. Each of the five output cables is 100 ft. long and terminates in a test box containing an attenuator with six outputs, giving voltages of 10 mV, 3.2 mV, 1 mV, 320 μV, 100 μV and 32 μV. These steps have been chosen to give a quick test of the D.C. restoration properties of the receiver under test. If the picture brightness is adjusted to give the correct black level for an input of say 1 mV, and the input is then reduced to 320 μV, the original black level will become the new white level, *i.e.*, the picture should just be blacked out.

In order to monitor the modulated R.F. signal, a single stage 45 Mc/s. amplifier is included to amplify the signal voltage appearing across the 10-ohm. load resistance. This amplifier feeds a diode detector and a cathode follower output valve, for connexion to the monitor circuits.

Sound Carrier

In general, this unit is very similar to the vision unit, the carrier frequency output being derived from a 6.91 Mc/s. quartz crystal oscillator, with subsequent trebling and doubling up to 41.5 Mc/s. The modulated amplifier consists of a single AC/SP1 valve, suppressor grid modulated. Internal sine wave modulation at approx. 30 per cent. level is provided from a 400 c/s. oscillator, and provision is made for external modulation such as from an audio oscillator from gramophone records.

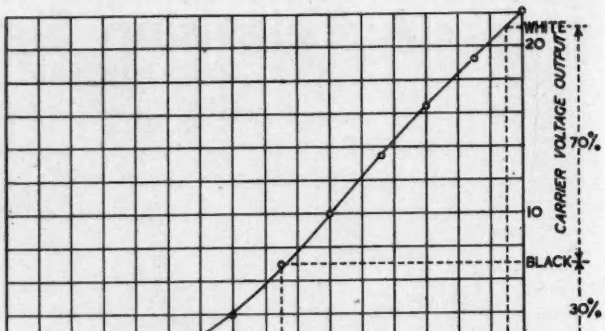


Fig. 10. Modulation characteristic.

The output signal is developed across a 100-ohm resistance, which feeds a cable to the output of the vision unit. Here the signal is attenuated, and the output mixed with the vision signal. The sound signal R.F. output is monitored by means of a diode-pentode valve, detecting and amplifying the signal appearing across the 100-ohm resistance. The valve feeds a loudspeaker which may be switched on or off at will.

Monitors

In an equipment of this type, it is most essential to have complete monitoring facilities available, both to maintain a constant check on the quality of the output, and also to assist in rapid location of any fault that may develop. Two monitors are provided, a picture monitor and a waveform monitor.

The Picture Monitor

The reproduction of the monoscope pattern may be checked at several points in the equipment by means of the picture monitor. The unit has three separate sections.

(1) The monitor cathode-ray tube with its supply circuit.
(2) The scanning circuits.
(3) A two-stage video amplifier to adjust the signal level to that required by the tube.

The complete circuit diagram is shown in Fig. 11.

A 9-in. magnetically operated cathode-ray tube (CRM91) is used, with an anode voltage of 6 kV. The cathode potential is obtained by means of a potentiometer across the 6 kV supply, and one side of the tube heater is connected directly to the cathode. The signal from the output of the video amplifier is coupled to the tube grid.

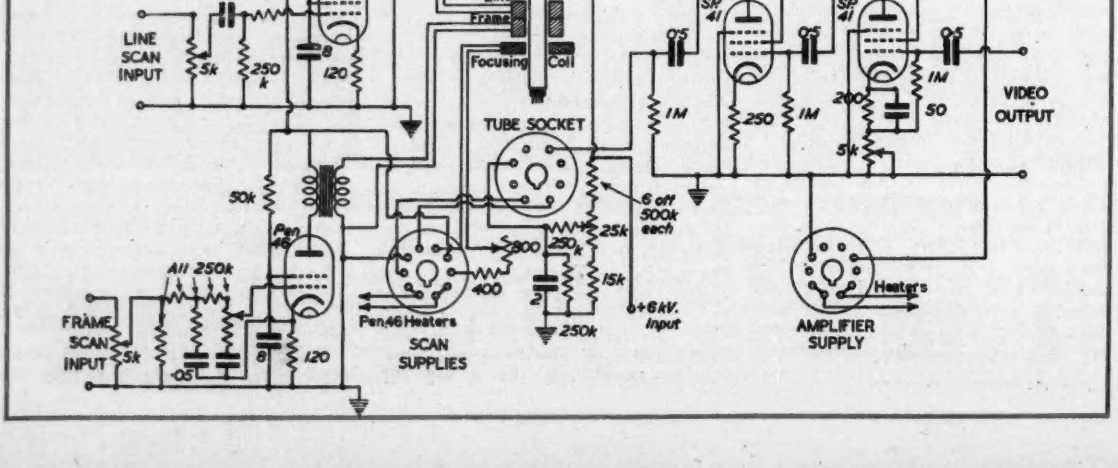


Fig. 11. Picture monitor.

Magnetic focusing is used in conventional manner, a separate voltage supply being used for the focusing coil, with a variable series resistance for adjustment. The line and frame sweep voltages are obtained from the monoscope scanning generators, and are fed to the monitor scanning amplifiers and scanning coil system, which is exactly similar to that used with the monoscope, as described in Part 2 of this series. The amplifiers use PEN 46 valves feeding a low impedance scanning coil system through step down matching transformers.

The video amplifier consists of two stages, using SP41 valves with anode loads of 1,500 ohms and 2,000 ohms respectively. Series inductance compensation according to the relation $L = 0.4CR^2$ is included. Variable cathode degeneration in the first valve cathode circuit is used for gain control, and fixed cathode degeneration is used in the output stage to minimise distortion due to valve characteristic curvature.

Waveform Monitor

This monitor is provided as a means of checking the signal waveform at various points in the equipment, and also to facilitate the adjustment of the impulse generator circuits. It utilises a 5-in. electrostatic cathode-ray tube with a 2 kV anode supply. The horizontal time base is sinusoidal at 50 c/s., a small voltage in quadrature being applied to the vertical plates to give an elliptic scan. The sweep voltage is obtained from the mains supply via a step-up transformer and is variable from zero up to 750 volts R.M.S. By this means the horizontal sweep amplitude may either be reduced so that the whole ellipse is visible, when a complete frame may be viewed, or increased so that the ellipse is expanded until a line interval may be viewed.

It is hoped to include in this monitor means for viewing the actual modulated envelope of the 45 Mc/s. output signal by switching the vertical plates to a tuned circuit fed from the output of the modulated amplifier.

Impulse Generator

The impulse generator section of the equipment consists of three units—the impulse generating and mixing unit, the multivibrator locking unit, and the power supply unit. In this article it is not proposed to describe these units in detail, the following paragraphs will give a general outline of their operation.

The master oscillator operates at 10,125 c/s. and feeds an amplifying stage which has two separate outputs.

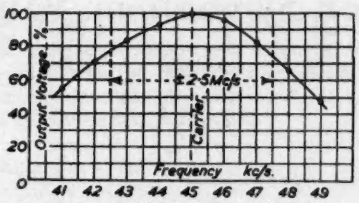


Fig. 9. Frequency response of amplifier.

The first output consists of pulses at 10,125 c/s., which, after shaping, form the line frequency synchronising impulses. The second output consists of pulses at double frequency, *i.e.*, 20,250 c/s., which, after further mixing and shaping, form the frame synchronising impulses. The frame impulse master stage is a multivibrator, producing impulses which control the number of frame impulses per complete framing signal, and also the rate at which the framing signals are repeated. These complete frame signals are then mixed with the line signals to form the complete mixed synchronising signal, which is then finally squared.

In order to lock the line and frame impulses together in the correct time relationship, the frame pulse master stage is controlled from the 20,250 c/s. pulse by means of two intermediate multivibrators. The first is synchronised at 1/9th of the above frequency at 2,250 c/s. and the second at 1/9th of this frequency at 250 c/s. The 250 c/s. output is used to synchronise the frame pulse master stage at 50 c/s. Finally, the frame signal is locked to the 50 c/s. mains frequency by means of a phase comparator circuit.

Conclusion

This series has given an account of the experimental television signal generator as the design stood at the outbreak of war in September, 1939. Since the termination of hostilities the work has been recommenced, the design of unfinished sections being continued. It is intended to redesign various circuits to incorporate improvements in circuit technique evolved during the war.

In conclusion, the author wishes to thank the directors of the B.T.H. Co., Ltd., for permission to publish this work, and to acknowledge the help of Mr. T. H. Kinman, under whose direction the work was carried out, and Mr. D. J. Mynall, who collaborated with the initial planning of the equipment and who was responsible for the design of the impulse generator section and the scanning circuits.

TELEVISION COMMENTARY

Drama enthusiasts have had a gala month of twelve good plays. When the novelty of television has waned, will it be possible to maintain this high standard? Radio drama has set the precedent of two performances only. It is surprising if television casts, except when they are brought complete from the theatre, are content to rehearse for this only. A surfeit of even excellent entertainment is possible, and viewers, however enthusiastic, would probably be satisfied with fewer plays and longer runs.

"St. Joan" came so superbly through the severe test that some viewers said boldly that it was better television than theatre. Some of the static scenes for which the stage seems too big, acquired a new intensity within the narrow limits of the screen, and with the added poignancy of close-ups of the maid and the chief characters. There were, however, camera mistakes, as, for instance, when Joan first blundered onto the stage through two doors simultaneously. Fans have been known to claim this sort of picturesque defect as one of television's assets which stress its authentic difference from the piecemeal production of films. Still, errors are not really improvements.

Some of the most pleasing pictures have been of instrumental soloists; Sidonie Goossens' harp recital was an exquisite performance, to mention only one.

The Brains Trust, so familiar to the ear, made a welcome, though nervous, début. One hopes they will recover from their stage fright and appear again. For captivating personality, I would give the month's television prize to Edric Connor, the West Indian singer, who wins by simply being himself, in spite of the unpleasant white flaring on the screen caused by his dark jacket. This again seems to be one of television's inherent defects at present.

Announcing is a straightforward job, but the struggle to make it into an act goes on. Announcers' dolls and telephones and easy chairs, borrowed, it would seem, from recent American television pranks, do not help television to grow up. Why not sound announcing only, with an occasional appearance, until the teething period is over?

JEAN BARTLETT.

Suggested Rules for Symbols in Valve Nomenclature

The British Radio Valve Manufacturers' Association has recently issued a set of suggested symbols which, it is proposed, shall be used in future technical literature issued by its members. Extracts from the rules are given below, and the Association invites comment on them

IN choosing the symbols the convenience of their production with standard printer's type as well as on a typewriter has been borne in mind.

With the exception of symbols for voltage and current the following general rules apply:

(a) Symbols applying inside a valve should be denoted by subscript letters in small type.

(b) Symbols applying outside a valve shall be denoted by subscript capital letters.

Values of voltage or current are denoted by capital letters except that instantaneous values shall be denoted by letter symbols in small type.

When the subscript consists of two groups of symbols representing the terminal points between which a measurement is made, the two groups shall be separated by a hyphen, *e.g.*, insulation resistance between anode and cathode = r_{a-k}.

When two subscripts are used to qualify the same symbol, the second may be in brackets, *e.g.*,
R.M.S. voltage on an anode = $V_{a(rms)}$

In multiple valves the respective electrodes may be distinguished by adding one of the following letters in small type as a subscript:

Diode = *d* Hexode, Heptode
Triode = *t* Octode, etc. = *h*
Tetrode = *q* Rectifier = *r*
Pentode = *p*

Two or more similar electrode systems can be distinguished by an apostrophe or tick (′), one for the first electrode system, two for the second electrode system, and so on.

If more than one grid is present, forming part of the same section of the valve, the grids shall be distinguished by adding a figure as a subscript, the figure showing the sequence of grids counting from the cathode. A similar convention applies to a sequence of anodes.

Secondary emission electrodes shall be considered as cathodes; the primary cathode is denoted by k_1 and the secondary cathodes by k_2, k_3, etc.

Where necessary, the polarity of the filament may be indicated:

f_{+ve}, f_{-ve}

Tappings on filaments or heaters shall be indicated by use of the suffix: "$_{tap}$", *e.g.*, h_{tap}.

The following auxiliary subscripts may be used:

Battery or other source ..... = b
Inverse (voltage or current) = inv
Ignition (voltage) ..... = ign
Extinction (voltage) ..... = ext
Input ..... = in
Output ..... = out

Examples

Voltage:
Anode voltage ..... = V_a
Voltage on control grid = V_{g1}
Supply voltage for anode = $V_{a(b)}$
Filament voltage D.C. ... = V_f
Filament voltage A.C. (RMS) ..... = $V_{f(rms)}$

Power:
Anode dissipation ..... = w_a
Output power ..... = w_{out}
Grid 2 dissipation ..... = w_{g2}

Resistance:

	Internal.	External.
Anode resistance...	r_a	R_a
Insulation, heater to cathode	r_{h-k}	

Capacitance:
Capacitance (cold)
anode to all other electrodes ..... = c_{a-al}
anode to Grid 1 ..... = c_{a-g1}

Electrode Symbols

Electrodes shall be denoted by the following symbols:

Anode	a
Cathode	k
Grid	g
Heater	h
Filament	f
Fluorescent screen or other target	t
External conducting coating (metallising)	M
Internal conducting coating	m
Deflector electrode	x or y
Internal shield	s

Symbols for Electric Quantities

The following symbols shall be employed:

Direct voltage	V
Alt. voltage R.M.S.	V_{rms}
Alt. voltage mean	V_{av}
Peak voltage	V_{pk}
Amplification factor	μ
Slope (mutual conductance)	g_m
Conversion conductance	g_c
Sensitivity (cathode-ray tube or photo-cells)	S
Distortion	D
Direct current	I
Alt. current R.M.S.	I_{rms}
Alt. current mean	I_{av}
A.C. peak current	I_{pk}
No signal current	I_0
Peak inv. voltage	P.I.V.

Examples of Electrode Terminology used for Basing Connexions, etc.

Full-wave rectifier	a′ - a″ - k - h - h
Triode	a - f - f - g
Triode pentode	k - g_1 - a_t - h - h = g_{1p} - g_{sp} - g_{3p} - a_p
Double pentode	k′ - k″ - a′ - a″ - g_1′ - g_1″ - g_2′ - g_2″ g_3′ - g_3″ - h - h
Double-diode pentode	k - a_d′ - a_d″ - a - g_1 - g_2 - g_3 - h - h

	Inside Valve	Outside Valve
Resistance	r	R
Reactance	x	X
Impedance	z	Z
Admittance	y	Y
Mutual inductance	m	M
Capacitance	c	C
Valve capacitance (working)	c_w	—
Power	w	W

Microphones *Part IV (conclusion)*

"Ribbon Velocity" Microphones and Combined Types

By S. W. AMOS, B.Sc.,* and F. C. BROOKER, A.M.I.E.E.*

Velocity Types in General

THE elementary theory of "ribbon velocity" microphones was discussed in Part II. Microphones operating on this, the differential pressure principle, are used extensively to-day in this country and the U.S.A. They are not quite so robust as moving-coil types and, being rather susceptible to the effects of winds or draughts, are not much used outdoors except for "lip" types.

All ribbon velocity microphones are roughly of the shape shown in Fig. 1. They consist of a permanent magnet carrying soft iron pole pieces giving a parallel magnetic field in which the diaphragm (which takes the form of a thin aluminium ribbon) moves. The clamps of the ribbon have, of course, to be of non-magnetic material (brass is generally used) to prevent magnetic short-circuiting of the gap), and are electrically insulated from the pole pieces. For a microphone of the "velocity" type to operate satisfactorily up to 9,000 c/s. (the R.C.A. ribbon type is an example of such an instrument) the dimensions of the pole pieces have to be such that the shortest path between the front and the back of the ribbon measured around the pole pieces is not greater than $\lambda/2$ at this frequency. At 9,000 c/s. $\lambda/2$ is equal approximately to 0.75 in. so that the pole pieces need to be particularly small in cross-sectional area in order to give this desired value of path difference. This may be achieved by making the pole pieces thin, and as they then become incapable of carrying the necessary flux, the flux is led to the pole pieces at various points by the auxiliary limbs visible in Fig. 1. Also, as explained in Part II, the mechanical resonant frequency of the ribbon has to be very low so that, over most of the audible range, the ribbon is mass-controlled. This is essential in order to secure a level frequency response. The ribbon is generally of very thin aluminium and usually has a resistance of the order of 0.1 ohm. This low output resistance makes it essential to use a step-up transformer immediately following the ribbon.

* Engineering Training Department, B.B.C.

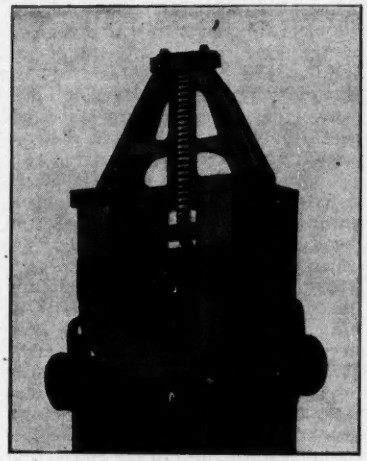


Fig. 1. An early R.C.A. microphone.

This is usually accommodated in the bottom of the microphone case and, in the B.B.C. model, steps the ribbon resistance up to 300 ohms. The ribbon is corrugated horizontally, the reason being, if the ribbon is thick (say 0.0002 in.), to provide sufficient compliance to give a low resonant frequency. With thinner ribbons the natural compliance of the flat ribbon is itself sufficient and corrugations here are frequently employed to prevent the ribbon from curling up at the edges and so becoming rigid. The ribbon is so lightly tensioned that it is necessary to protect it from damage, or from being blown out of the magnetic gap by draughts, by one or more screens lined with chiffon. It is the outermost of these screens which gives the ribbon microphones their characteristic appearance.

In the model illustrated in Fig. 1, the overall width of the ribbon and the pole pieces is too small for pressure doubling effects to be troublesome within the usual audio-frequency range. For the same reason there is no deterioration in relative high-frequency response as the source of sound is moved around the microphone; in other words, the shape of the polar diagram does not vary with frequency. "Top cut" can, however, occur if sound waves strike the ribbon at a very oblique angle to its length and whenever such a microphone is slung high above an orchestra it is advisable to tilt it so that the sound waves strike the ribbon at approximately normal incidence. Frequency distortion, this time in the form of bass emphasis, can also occur if the sound source is too close to the microphone for the reasons discussed in Part II. It has sometimes been claimed that this bass emphasis made crooning possible!

Since the ribbon is exposed to the sound waves back and front, the microphone is perfectly double-sided, and so performers may be positioned on both sides. This is particularly convenient in broadcast performances involving soloists and an orchestra, and also for intimate talks programmes (such as Brains Trusts). It is fairly obvious that a ribbon microphone will be completely unresponsive to sounds arriving at 90° incidence to the ribbon, *i.e.*, along the line of the pole pieces. Even if the sound source is situated in the dead area, the minimum is masked indoors by reflexions at walls and floors, etc. It has already been pointed out that, as the angle of incidence of sound is varied from 0° to 90° in the horizontal plane, the output level falls, actually according to a cosine law, but the fall in level is approximately the same for all frequencies so that no frequency distortion occurs. This fact is used to good effect in drama productions: a performer in the "dead" area sounds a long way off even though he may be a few feet from the microphone, and a performer moving towards the dead area and speaking at a constant level gives the impression that he is walking rapidly away. A cosine law, plotted in terms of polar co-ordinates and on a linear amplitude scale, gives a circle, so that the polar diagram illustrating the variation of sensitivity of a ribbon microphone takes the familiar "figure-of-eight" shape shown in Fig. 2. In this the output of the microphone for sound arriving at an angle of incidence θ is represented by the length of the vector OP. Maximum output occurs for normal incidence, represented by vectors OA and OA' and

zero for angles of incidence of 90°. Thus the difference in output level between the output at θ and that at 0° is given by $-20\log_{10}\cos\theta$ db. The curve of this function is given in Fig. 3. If we are prepared to accept a variation of ± 2 db. in the output then it is possible to say that the output level of the microphone is substantially uniform for angles of incidence between 0° and 50°. Hence there is an arc subtending an angle of 100° on both sides of the microphone within which the performers may be placed, as shown in Fig. 4. This total 200° arc should be compared with the 60° arc available with the moving-coil microphone.

In order that speakers or orchestras shall sound pleasing to the ear it is essential to preserve a certain ratio of direct to indirect (or reflected) sound in the pick-up of the microphone. The shape of the polar diagram of a microphone has an important bearing on this question. On account of the figure-of-eight shape of the polar diagram of a velocity microphone this type is less sensitive to indirect sound than an omnidirectional type. In fact, the response of a velocity microphone to indirect sound is only $1/\sqrt{3}$ that of an omnidirectional type. Hence the relative speaking distances for the two microphones to give the same ratio of direct to indirect sound are in the ratio of $\sqrt{3}:1$. One may use, therefore, a more "distant technique" with velocity microphones than with omnidirectional types, and this, combined with the larger useful arc, makes ribbon microphones far more flexible in use than other types.

The B.B.C.-Marconi Microphone

The appearance of this microphone is familiar to everyone for many photographs of it have been published. An exterior view headed Part I of this series. It was developed by the Research Department of the B.B.C. and is manufactured by Marconi's Wireless Telegraph Company. One important difference between this and other types is that the B.B.C. type has large pole pieces. The distance around the pole pieces actually measures 1½ in., which means that the velocity principle carries the response up to about 4,500 c/s. (for which $\lambda = 3$ in.). Above 4,500 c/s., due to the decreasing wavelengths, the output of the microphone falls off rather sharply. However, the cavities formed by the ribbon and the chamfered pole pieces are broadly resonant over the range 4,500-9,000 c/s., and their effects, together with the obstruction or diffraction effect due to the overall width of the ribbon and pole pieces, are such as to carry the response of the microphone up to 9,000 c/s. Throughout this range the behaviour may be compared with that of two pressure microphones placed back to back. The ribbon is of aluminium 2½ in. long, ¼ in. wide, and the thickness was 0.0002 in. in early models but was later decreased to less than 0.0001 in. in order to minimise certain resonance noticeable with the thicker ribbon. The ribbon is made resonant at a frequency below the lowest audible value, so that it is mass-controlled throughout the audible frequency range. A tensioning device (visible under the lower clamp of the ribbon in Fig. 5) enables this adjustment to be carried out empirically. For finding the resonant frequency a direct-reading frequency-measuring bridge circuit was used in which the ribbon itself forms the *LC* circuit of an oscillator, but the ribbon is so slack in the later models that no resonant frequency is measurable. A typical frequency response of a ribbon microphone is given in Fig. 6. The slight fall at 9,000 c/s. may be corrected by frequency discriminating networks in the A.F. amplifier immediately following the microphone.

In the B.B.C. model the leads from top and bottom are arranged as shown in Fig. 5. There are two leads from the top, arranged symmetrically at back and front of the ribbon and joined together again at the bottom. This arrangement is adopted to minimise noise pick-up from magnetic fields which is frequently a nuisance with ribbon microphones. The two wires, together with the ribbon, form two "loops" in the same plane; any E.M.F. induced in one loop will be cancelled out by the pick-up in the other. These wires are adjusted empirically during initial tests on the microphone, and as much as 30 db. reduction in magnetic pick-up has been achieved in comparison with the earlier models.

Another interesting feature is that the metal cover, which contains the matching transformer, is coated on the inside with a vibration deadening

Fig. 2. Polar diagram of an ideal ribbon velocity microphone.

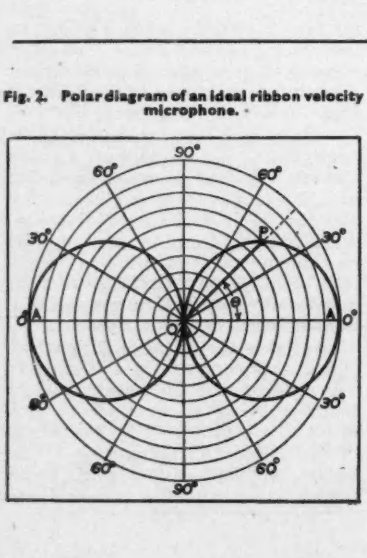
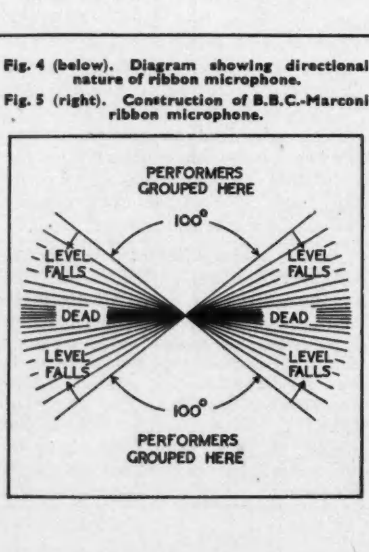
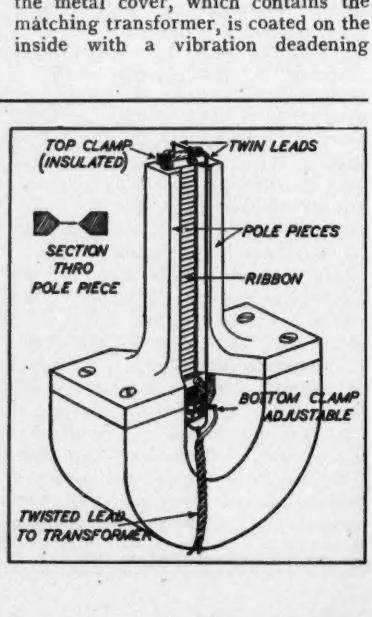


Fig. 4 (below). Diagram showing directional nature of ribbon microphone.

Fig. 5 (right). Construction of B.B.C.-Marconi ribbon microphone.





compound to prevent ringing. The sensitivity of the earlier type of B.B.C. microphone, with a cobalt-steel magnet of flux density 1,600 gauss, was −76 db., but a modified version, using a Ticonal magnet with approximately twice the useful flux density, gives an approximate 6 db. improvement on this figure.

The B.B.C.-Marconi "Lip" Ribbon Microphone

For the purpose of making running commentaries, where an unusually large amount of background noise is likely to be encountered, it is useful to have a microphone which can be used at very close range. Originally, moving-coil microphones were used, but the special properties of the ribbon velocity microphones have been put to good account in the design of the "lip" microphone.

From our considerations of spherical waves, we know that the low frequency response is increased considerably at short distances from a small sound source. This amounts to 20 db. rise at 100 c/s. for a radius of 2½ in. Since this increased output can then be attenuated electrically or acoustically, it follows that the response to interfering sound will similarly be reduced. Although only the low-frequency components of the interference are removed in this way, it is found that this eliminates much of the loudness in the interfering sounds met in outside broadcast work.

The construction of the microphone is illustrated by Fig. 7, where it will be seen that it has a very small ribbon (actually 1 in. × 0.1 in.) situated in the gap of a correspondingly small horse-shoe magnet. The microphone assembly is slung in a cradle of 8 springs (to prevent jarring noises when the microphone is handled) and enclosed in a perforated metal case lined with gauze. An unusual feature is that the body of the magnet is situated between the mouth and the ribbon. This screens the ribbon from direct draughts from the speaker's mouth, which would give rise to unpleasant "bumps" on transmission. It tends, also, to give a top-cut due to the shorter waves being reflected at the surface of the magnet and so not reaching the ribbon, but this is not really objectionable as it occurs above 6,000 c/s. and has a negligible effect upon speech. A small

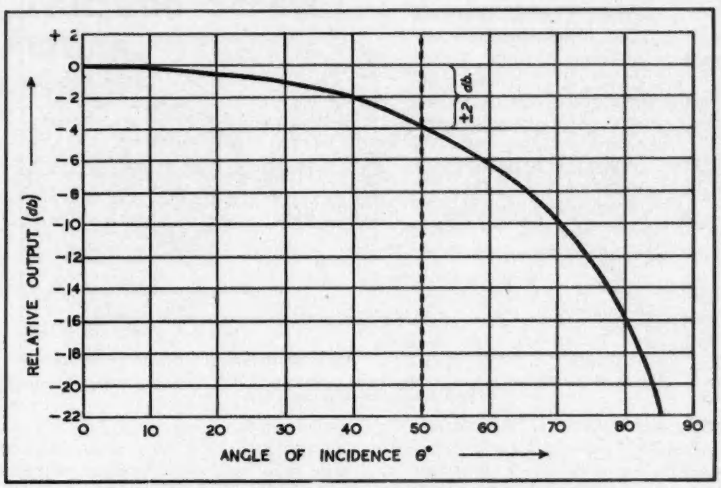


Fig. 3. Graph illustrating directivity of ideal velocity microphone.

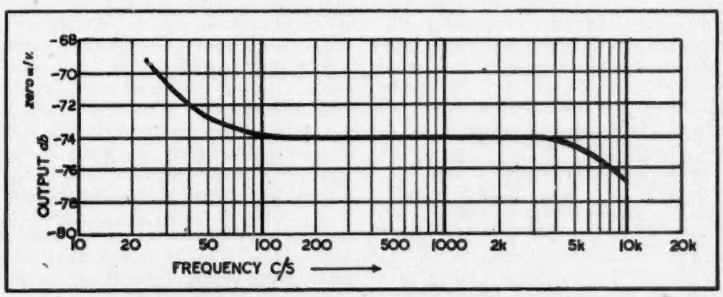
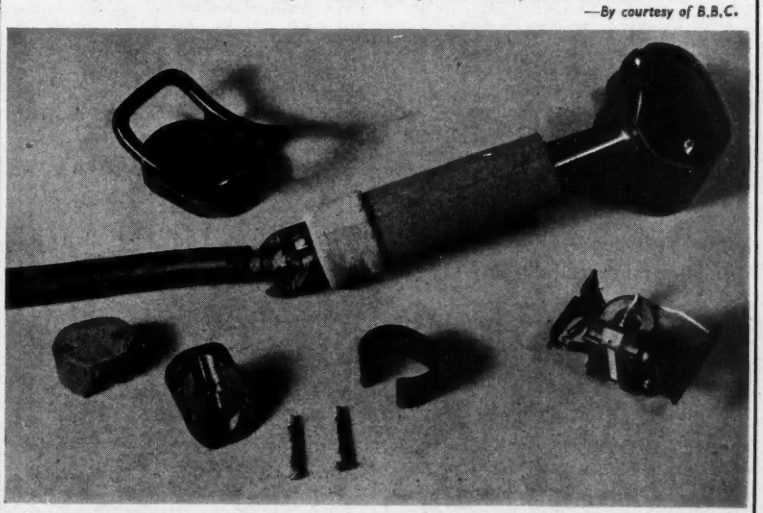


Fig. 6. Typical response curve for a ribbon velocity microphone.

Fig. 7. B.B.C.-Marconi "Lip" ribbon microphone. Components unassembled.
—By courtesy of B.B.C.



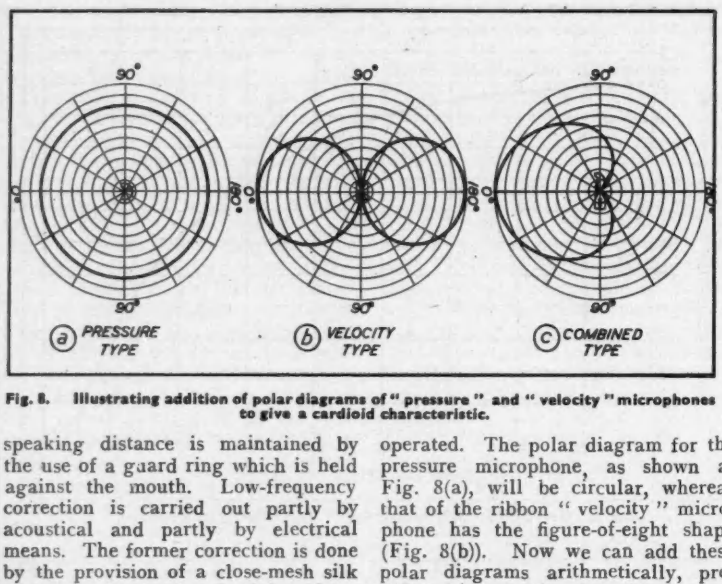


Fig. 8. Illustrating addition of polar diagrams of " pressure " and " velocity " microphones to give a cardioid characteristic.

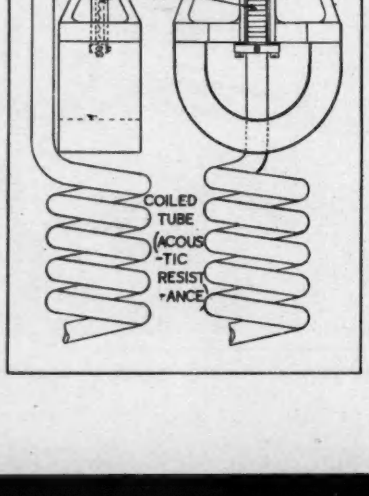
speaking distance is maintained by the use of a guard ring which is held against the mouth. Low-frequency correction is carried out partly by acoustical and partly by electrical means. The former correction is done by the provision of a close-mesh silk screen in front of each ribbon face. This has the effect of adding a series acoustical resistance to the mass-controlled ribbon motion, and so reduces the plane-wave response at low frequencies. While it would be possible to carry out all the low-frequency correction in this way, it was thought desirable to effect part of it by an electrical network, made variable to accommodate variations in the timbre of the speaker's voice. (He is quite likely to go falsetto during an exciting commentary!)

Owing to the usual low impedance of the ribbon, a matching transformer must be used close to the microphone, and in this case is made especially small so as to fit in the handle. The sensitivity of the microphone, plus equaliser, is −91 db., compared with 1 volt per dyne/sq. cm. at 300 ohms impedance, but the actual output under operating conditions is considerably greater owing to the close proximity of the ribbon to the speaker's mouth.

Combined " Pressure " and " Velocity " Types

We have seen that " pressure " and " velocity " microphones have quite different directional characteristics, and it is not surprising that attempts have been made to combine the two types in order to produce special directional qualities. To explain the principle, consider two entirely separate microphones placed at the same point, one of the " pressure " type and the other " velocity " operated. The polar diagram for the pressure microphone, as shown at Fig. 8(a), will be circular, whereas that of the ribbon " velocity " microphone has the figure-of-eight shape (Fig. 8(b)). Now we can add these polar diagrams arithmetically, provided due attention is paid to sign. The result of adding the polar diagrams, taking the above remark into consideration, is to give a diagram of cardioid shape as shown in Fig. 8(c) (provided that the maximum of the figure-of-eight diagram equals that of the circle), obviously a very useful shape since it represents a one-sided microphone with a very wide useful angle. The shape will, however, vary with frequency somewhat, since the " pressure " curve of Fig. 8(a) varies with frequency as shown in Part III.

Fig. 9. One method of achieving a cardioid polar diagram.



Although two separate microphones connected in series externally may be used to give a cardioid polar diagram, various designs have been produced which combine the two types in one case. The ribbon microphone of Fig. 9 is an example of such a type. In this the ribbon is supported at its middle point, one half being closed in at the back so as to make it pressure operated. To obtain a flat frequency response it is necessary to ensure that the velocity of this " pressure " ribbon shall be in phase with the pressure component of the wave. From the following expression for the phase angle by which the velocity of the ribbon lags behind the instantaneous pressure of the sound wave, derived from the differential equations of Part I:

$$\tan\theta = \frac{m\omega - \frac{s}{\omega}}{r}$$

it is clear that r must be very large to make θ approach zero. The acoustic overall impedance of the ribbon together with the acoustic circuit behind it must be predominantly resistive in nature and the resistance must be large enough to swamp out the mass reactance of the ribbon. In Part I it was explained that any desired ratio of reactance to resistance in an acoustic element could be obtained by the choice of suitable dimensions. Here the resistance is made great by using a long pipe lagged internally. To conserve space the tube is coiled up so as to form a labyrinth.

Other mixed types of microphone employ a moving-coil or crystal movement for the " pressure " type and a ribbon for the " velocity " type, both included in one case. Suitable matching must be introduced before the outputs are added together—usually by connecting them in series.

In conclusion, the authors wish to express their thanks to the engineering division of the B.B.C. for their permission to publish photographs and data concerning their microphones, and, in particular, to Mr. D. E. L. Shorter, of the B.B.C. research department, who kindly checked the accuracy of this manuscript and offered many valuable suggestions. Thanks are also due to Marconi's Wireless Telegraph Company, Standard Telephones and Cables, and Rothermel-Brush for information and photographs.

Clearance between Nut and Screw Prior to Plating

By JOHN BRADSHAW*

Introduction

THE dimensions of screw threads before plating or the application of a protective coat of thickness T are laid down in B.S.84.1940 for Whitworth threads and B.S.1095.1942 for metric threads. The values quoted for Whitworth threads are − 0.001 in. below the specified lower limit, for external screw threads, and + 0.001 in. above the specified upper limit for internal threads. This, as will be seen later, permits a coat of 0.00023 in. maximum per surface on mating parts. It is obvious from the above statement that when heavy protective coats are required, as instanced in tropical protection, plus and minus 0.001 in. on mating parts does not constitute sufficient clearance for mating without interference, and unless care and forethought are exercised in allocating additional clearance, the immediate assumption is to make the clearance four times the required plating thickness. This is, however, an erroneous assumption, as will be shown.

Conventions Used

Diameters are measured normal to the axis.

Thickness of plating or protective coating is measured normal to the surface.

Reference to diameters implies nominal diameters and takes no account of manufacturing tolerances.

When allocating clearance to permit plating, the internal screwed member will be produced to conform with standard nominal dimensions, *i.e.*, standard taps.

Fundamental Considerations

Consider the fundamental thread form shown in Fig. 1.

If T represents the desired thickness of plating normal to the surface, then D_1 will increase to D_2 and D_3 to D_4. That is, D_3 increases by $2T$. But D_1 increases by something greater (*see* Fig. 2).

$ET = T/\sin\phi$. Therefore D_1 increases to D_2 by a factor $2T/\sin\phi$.

It follows, therefore, that for external threaded screws the major and core diameters will, after plating, increase by $2T$, while any diameter measured in relation to the flanks (*i.e.*, the "effective diameter") will, after plating, increase by $2T/\sin\phi$. Conversely, for internal threaded screws, the major and core diameters will decrease by $2T$ after plating, while any diameter measured in relation to the flanks (*i.e.*, the "effective diameter") will, after plating, decrease by $2T/\sin\phi$. It is evident that clearance to permit plating must be calculated, not in terms of $2T$, but in terms of $2T/\sin\phi$. When the mating parts are both plated the required clearance is of the magnitude $4T/\sin\phi$. But when only one of the mating parts are plated and the other left clean, the clearance is of the magnitude $2T/\sin\phi$.

Symbols Used

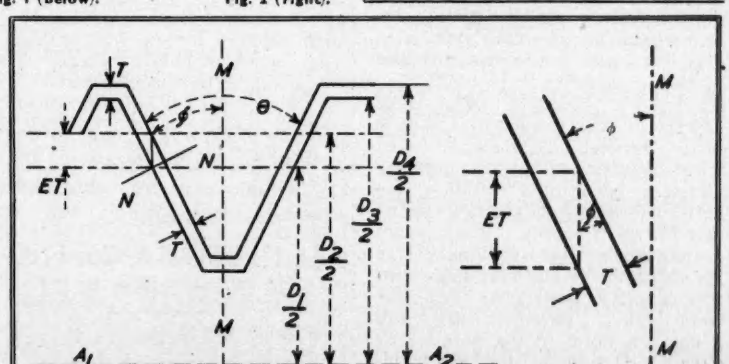
A_1, A_2	Axis of screw or nut
D_1	Effective diameter before plating
D_2	Effective diameter after plating
D_3	Major diameter before plating
D_4	Major diameter after plating
ET	Effective thickness of plating
M	Normal to screw axis
N	Normal to thread flank
O	Apex of thread
P_1, P_2	Crests of adjacent threads
T	Thickness of plating or protective coat, measured normal to the surface
θ	Thread angle
ϕ	Flank angle

Application to Production:

1. Both Members are to be Plated

In as far as it is practicable, the internal screwed member should be produced to the nominal dimensions laid down in the relevant specification, before plating. After plating, these dimensions will be reduced by $2T/\sin\phi$. The external threaded member will have its nominal dimensions reduced by $4T/\sin\phi$ before plating. After plating these dimensions will have increased by $2T/\sin\phi$.

Fig. 1 (below). Fig. 2 (right).



2. Only One Member to be Plated

(a) *External member plated.*
Internal member unplated.
Finish internal screw to standard dimensions.
Reduce external screw diameters by $2T/\sin\phi$ before plating.

(b) *External member unplated.*
Internal member plated.
Finish internal screw to standard dimensions and plate it.
Produce external screw with diameters reduced by $2T/\sin\phi$.

Some Mnemonics

Whitworth threads.—For every 0.0001 in. thickness of plating to be applied, the external screwed member must have its standard nominal dimensions reduced by 0.00086 in. for conditions laid down above.

B.A. threads.—For every 0.0001 in. thickness of plating to be applied, the external screwed member must have its standard nominal dimensions reduced by 0.00098 in. for conditions laid down in above.

In general, it would be sufficiently correct to state 0.0001 in. plating represents 0.001 in. reduction in diameter.

Table of reducing values for various thicknesses of plating

T	Both Members Plated		One Member Plated	
Units = .0001 in.	Reduce external member by		Reduce external member by	
	Whitworth	B.A.	Whitworth	B.A.
1	0.00086	0.00098	0.00043	0.00049
2	0.00172	0.00196	0.00086	0.00098
3	0.00258	0.00294	0.00129	0.00147
4	0.00344	0.00392	0.00172	0.00196
5	0.00430	0.00490	0.00215	0.00245
6	0.00516	0.00588	0.00258	0.00294
7	0.00602	0.00686	0.00301	0.00343
8	0.00688	0.00784	0.00344	0.00392
9	0.00774	0.00882	0.00387	0.00441
10	0.00860	0.00980	0.00430	0.00490
11	0.00946	0.01078	0.00473	0.00539
12	0.01032	0.01176	0.00516	0.00588
13	0.01118	0.01274	0.00559	0.00637
14	0.01204	0.01372	0.00602	0.00686
15	0.01290	0.01470	0.00645	0.00735

* Ferranti, Ltd.

BOOK REVIEWS

Electronics for Engineers

Edited by John Markus and Vin Zeluff. (McGraw-Hill, 1945.) Price in Britain, 36s. 390 pp. Many figures. Reference articles, charts and graphs from *Electronics* magazine.

As the editors of this book say, monthly magazines are not exactly convenient for reference when accumulated for a few years, nor are photostat facilities always available to everybody who could use them. Consequently, this volume will be welcome as a selection of 142 articles and data sheets from *Electronics* which requests have proved to be in greatest demand.

The years extracted are 1935-1944, with almost a third of the material from 1944 issues, a sixth from 1943, one article only from 1935 and a practically even distribution over the remaining years. The papers have been checked, condensed and retitled where necessary, uniformly styled for book presentation and arranged in 27 chapters which embrace a wide scope.

The subject-matter may be divided into two parts, namely general and special topics. Considering generalities, physical design of components covers permanent magnets, round-edge capacitors, self- and mutual-inductors and transformers for A.F. and R.F. (13 articles). The greater part of the book may be said to ease network design (67 articles), including vector conversions; 2-terminal networks, covering impedance generally, resistance combinations, capacitance at V.H.F., skin effect, various *RC* circuits, power factor, *LC* tuned circuits and rectifier circuits; 4-terminal networks, covering general performance, matching at A.F. and R.F., equalisers, filters (general, smoothing, low- high- and band-pass), transmission lines (general, parallel, concentric and waveguide). One or two special aspects of pliotron tubes include μ-factor estimation, filament resistance characteristics, secondary radiation, open-grid working and performance of standard tubes on 28-volt (aircraft) supply. C.R.T. photography and gas-tube grid control are investigated. Amplifier data cover D.C., A.F., R.F. power, V.F. and wide-band and A.C.-powered types, with a note on noise in the parallel *RC* circuit. Design of the single-tube phase-shift oscillator is simplified.

It should not be assumed that the actual organisation of this book is as given above. Unfortunately, the chapters seem to have been over-hastily chosen and arranged, and an alphabetical arrangement of chapter headings has been regrettably preferred to a natural sequence. Filters, for instance, appear under no less than five headings, as also matching. In at least one instance the retitling is not happy, as a valuable article by Schwarzmann on A.C.-powered amplifiers has been strangely retitled "Design of Electronic Control Circuits" and classified under "Industrial Control." On the other hand, the article by Mittelmann entitled "Design Chart for R-F Heat Treatment Generators" gives no idea of its subject and could be more usefully renamed "Electrode Conditions for Dielectric Heaters."

In view of the character of the work, it is a pity that it was not labelled "Electronics Reference Book," as this would have left the present title free for a further collection of appropriate articles dealing with applied electronics generally.

The faults mentioned do not seriously detract from the reference value of the book, but it is irritating to have to dive from one end to the other to find material on the same or cognate subjects. Apart from greater speed in becoming familiar with the contents (a necessary feature of all reference books), a logical sequence would show immediately the value of the material contained in any one section. This book will not *replace* any of the best handbooks, as its coverage is obviously patchy in places, but will rather be a valuable supplement, particularly in swift solution of practical problems, made easy by the clear style for which *Electronics* is justly renowned.

J. C. FINLAY.

Books reviewed in this Journal can be obtained from

H. K. LEWIS & Co. Ltd.
136 Gower Street, W.C.1

If not in stock, they will be obtained from the Publishers when available

The Cathode-Ray Tube Handbook

S. K. Lewer. 95 pp., 35 figs. (Sir I. Pitman & Sons, 6s. net.)

What is a handbook? The O.E.D. says "A small book or treatise, such as may be held in the hand." Mr. Lewer's book certainly conforms to the definition, but the reviewer's impression is that the word has come to connote more than a small book and rather implies a comprehensive book to hold when studying the apparatus and how it works. (Compare the "Morris Handbook.")

Any readers who share this impression will be disappointed if they expect a complete guide to the tube and its circuits.

Obviously, it cannot be done in 95 pages, but what Mr. Lewer has done is to give an excellent survey of the basic principles of the tube leading to the complete oscillograph, with a surprising amount of interesting allied information. The book should go well with beginners who are taking an interest in television tubes as well as those who have only seen an oscillograph from the outside.

G. P.

Radio-Communications

W. T. Perkins and R. W. Barton. (Geo. Newnes, Ltd., 12s. 6d. net.) 312 pp. with 184 illustrations.

The authors have attempted, by a series of questions and answers, to cover the syllabuses of the City and Guilds of London Institute examinations in radio communications, Grades 1, 2 and 3. Such a book, if used in the right way, should prove of considerable value to all who enter for these or similar examinations.

Although the arrangement is good and the presentation attractive, it is doubtful if the present edition can claim to reach the standard of work it sets out to cover.

Chapter 1 includes the syllabuses of the above courses, and 17 pages of useful formulæ.

Components are dealt with in Chapter 2 and valves in Chapter 3.

There are, however, a number of slips in these sections.

The brief definition of a Class B amplifier on page 62 is misleading. The magnitude of the change of anode current may actually be greater than in a Class A amplifier. The polarity of the voltage shown across C4 in Fig. 50 is incorrect, and Figs. 50 and 51 have been interchanged. Space prevents a detailed reference to the other errors which occur in these two chapters, but it is suggested, if a second edition is produced, that these be completely rewritten.

Subsequent chapters have questions on receivers, transmitters, aerials, ship-shore radio, measuring instruments, and interference, and it is pleasing to note an improvement in the general level of these sections. The illustration of a cathode-ray tube in Fig. 138 could have been better chosen, and the authors appear confused about its construction.

The forty-four pages of Chapter 13 are devoted to the description of twenty-two experiments, starting with valve characteristics and concluding with a method of measuring mutual inductance. The value of these will be determined largely by the availability of apparatus with which to carry them out. Eight tables and three nomograms occupy the last section of this work, and are followed by a comprehensive index.

It is felt that if a little more care had been given to the preparation of the material and the elimination of inaccuracies, this book would have served a useful purpose and become a valuable addition to the library of any student.

C. N. YATES.

The "Trader" Year Book, 1946

(The Trader Publishing Co., Dorset House, Stamford Street, S.E., 10s. 6d.)

This is the seventeenth edition of the well-known Year Book for the radio and electrical trades, and although it still has an austerity cover, the contents are as useful as ever. They are: Legal Section for Radio Dealers, Trade Addresses, Wholesalers' Directory, and Classified Buyers' Guide. There are also lists of trade names, trade associations, and radio data. Subscribers to *The Wireless and Electrical Trader* can obtain copies at a reduced price. The book is essential to all starting their own radio business.

A Six-Channel Electronic Recorder

(*Continued from page* 235.)

The sequence of events following the depressing of the master recording switch will now be outlined:

(1) Shutter opened.

(2) Six cathode-ray tube beams switched on and calibration signal applied to amplifiers. Time trace lamp switched on.

(3) Calibration signal switched off and measurement signal switched on. Record number and Time Trace frequency number lamp flashed on.

(4) Cathode-ray tube beams switched off. Time trace lamp switched off and shutter closed.

Operation 4 is controlled by the footage control indicator, which determines the length of record taken.

The development of this six-channel electronic recorder follows the development of three-channel and four-channel electronic recorders which have been designed to fulfil other test and measurement requirements specified by the Royal Aircraft Establishment. The present-day demand for electronic equipment, such as these multi-channel electronic recorders for use in various industries, is inspired by the many advantages to be gained over the less flexible mechanical equipment previously used. For example, as compared with earlier mechanical equipment it has the advantage of a very much higher frequency response with greater sensitivity that is easier to control, and the advantage that small pick-up devices can be used situated immediately at the site of investigation while having electrical indication at a remote point. Multi-channel electronic recording, furthermore, enables phasing of a number of effects, allowing quicker operation to be obtained. This demand for electronic recording equipment illustrates the ever-growing importance of electronic test and measuring equipment in industry and particularly shows the importance of applied electronics, as exemplified in these electronic recorders, in the field of aeronautical research.

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NOTES FROM THE INDUSTRY

New Metal Detector

The "Cintel" Metal Detector, manufactured by Cinema-Television, Limited, will locate accurately to within an inch or two 6-in. pipes and the like buried up to approximately 2 ft. 9 in. below the surface of the ground, and will detect even small pieces of magnetic and non-magnetic metal embedded in timber or otherwise concealed to a depth of approximately 9 in. The detector comprises three parts, the search head with handle, the amplifier box, complete with battery, and headphones. The indication of the presence of metal is given by a distinctive note in the headphones. The amplifier weighs 6½ lb., and is carried over the shoulder of the operator. In cases where it is required to trace pipes, cables, conduits, etc., buried up to 30 ft. below the surface of the ground but exposed at any one point, the detector can be used in conjunction with an oscillator. Further information can be obtained from Cinema-Television, Ltd., Worsley Bridge Road, Lower Sydenham, London, S.E.26.

Mercury Switches

Salford Electrical Instruments, Ltd., manufacture a wide range of mercury switches including single pole switches, single pole changeover switches, types with ceramic liners for dealing with heavy currents, instantaneous types, time lag patterns, switches suitable for wide angles of tilt, and multi-contact switches for mechanical or electrical operation. These switches are filled with inert gas, and the ceramic liners are sealed in to prevent arcing taking place between the ceramic and the glass. One small type of switch which was used during the war for controlling the level of gun platforms will operate with a tilt of only three minutes of arc.

United Insulator Co., Ltd.

This company, which recently moved to Oakcroft Road, Tolworth, Surbiton, Surrey (Telephone: Elmbridge 5241), has issued a catalogue giving a complete description of their manufacturing programme. A price list for the trade is in preparation and will shortly be available.

The Lexington Pickup

Price Correction

The price quoted in last month's article on the Lexington Pickup gave it as £5 complete. This should have read £5 plus 25s. P.T. Sapphire needles are extra at 15s. 3d. tax included, and the transformer is 16s., or with mu-metal shield 30s. 2d.

City & Guilds (Engineering) College

New Head of Electrical Department

Prof. Willis Jackson has recently been appointed to succeed Prof. C. L. Fortescue as head of the Electrical Engineering Department at the City & Guilds Engineering College (Imperial College of Science and Technology). He has occupied the chair of Electrotechnics at Manchester University since 1938.

Prof. Fortescue, who is retiring at the end of the session, has been at the College since 1922, and is well known for his work on radio-communications. He was adviser to the Admiralty during the war of 1914.

Prof. Willis Jackson is chairman-elect of the radio section, I.E.E., and was formerly at the Metropolitan-Vickers Electrical Co., Ltd., and with Dr. Moullin at Oxford.

Change of Address

R.F. Equipment, Ltd., recently moved their works and offices to Langley Park, nr. Slough, Bucks. Telephone: Slough 22201.

Nature Query

I want to know
Why fireflies glow.
Do they carry tiny Exides
Slung under their bexides?

B. B.

—London Opinion.

Metal Coatings on Ceramics

(*Continued from page 242.*)

with an additional silver coating. The same method has been used for many years for silver-plating china tea and coffee pots. When simply covered with a burnt-on silver paint the metal coating is rubbed off after a few weeks by daily cleaning and polishing, whereas china pots first copper- and then silver-plated can be cleaned and polished daily for many years without the silver coating being removed.

Silver coatings lend themselves to subsequent soft-soldering either directly after being fired on to the ceramic, or after being reinforced by plating. The connexion is mechanically sound and free of electric losses since there is no trapped air between ceramic and metal coating, provided that the silver painting is properly done. Soldering of metal parts to a silvered ceramic has the following advantages compared with cementing the metal parts to the ceramic:

(1) The mechanical strength of a soldered connexion of metal to porcelain is greater than the adhesion of cement to porcelain.

(2) The elasticity of the thin metal coating compensates for any internal stresses set up by the difference in thermal expansion of metal and ceramic.

(3) Dielectric losses which occur if the metal part is connected to the porcelain by cement are eliminated. If the space between the metal part and ceramic has to be filled with cement, the cement layer can be short-circuited by a solder connexion between the metal part and the ceramic silver layer.

A completely air-tight solder joint can be made in this manner between a metal part and a ceramic part or between two silvered ceramic parts, or between a silvered glass part, a ceramic part and metal parts. This fact is of great importance in the manufacture of evacuated vessels either of metal or of glass into which wires or metal rods insulated and spaced by a ceramic are introduced.

As mentioned previously the burnt-on metal coating, owing to its elasticity and thinness, compensates for mechanical stresses set up by the different thermal expansion of the ceramic and the metal. For instance, in the case of a ceramic rod covered with a thin burnt-on silver coating its thermal expansion is solely determined by the thermal expansion of the ceramic. Although the coefficient of thermal expansion of both silver and copper is much larger than that of porcelain or steatite the metal coating does not move away from the ceramic surface even under heavy temperature variations. This refers only to ceramic silver coatings where the flux, after firing, provides for the necessary adhesion. Of this fact use is made in the manufacture of metallised ceramic coils. If the coil is made from a ceramic having a very small thermal expansion coefficient the dimensions of the coail and, consequently, its inductance change very little with varying temperatures.

The photos of silvered ceramic parts for capacitors and coils published in this article have been placed at the author's disposal by Messrs. Bullers, Ltd., whom he would like to thank for their courtesy.

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Permittivi
Di-Electri
(volts/mil)

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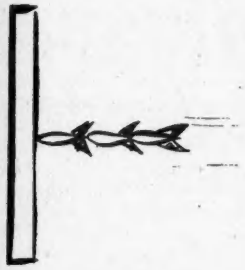

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TAS/SC 117

A Note on the Ardente Intercom: Systems

THE Intercommunication systems developed by the Ardente Acoustical Laboratories, Ltd., are claimed to incorporate a considerable number of operational and technical facilities not previously obtainable in the systems marketed by both American and British concerns in this country before the war.

Four different systems are available, which cover practically every possible application or requirement:

(1) "Duocall." A two-way system consisting of one Master and one Sub-Unit.

(2) "Selectacall," consisting of one Master and any number up to ten Sub-Units.

(3) "Multicall." A completely intercommunicating system, consisting of from 3-30 Master Units.

(4) "Mastercall." A combination system, consisting of up to eight Intercommunicating Master Units, each with its own "Personal" Sub-Units, from 1-7.

The systems incorporate visual signals, so that, for instance, any sub-unit attempting to call the Master when it is already talking to another unit gets a definite indication by the illumination of its "busy" lamp. Also, the Master Unit has an indication that someone else is trying to contact it by the illumination of the "call waiting" lamp.

Further features are that there is no hum when the Units are in a "stand-by" state, and there is complete silence on all units when no calls are being made.

Both Masters and Sub-Units are contained in moulded bakelite cabinets, the overall size being 12 in. long by 8 in. high by 5¾ in. deep. Black is the standard colour, but other colours can be provided at a slight additional cost.

The same company have also produced a complete set of sound equipment for Public Address and Intercommunications. The "Loud-Hailer" produced in large quantities for Service use is so well known that the compound word has become absorbed in the language.

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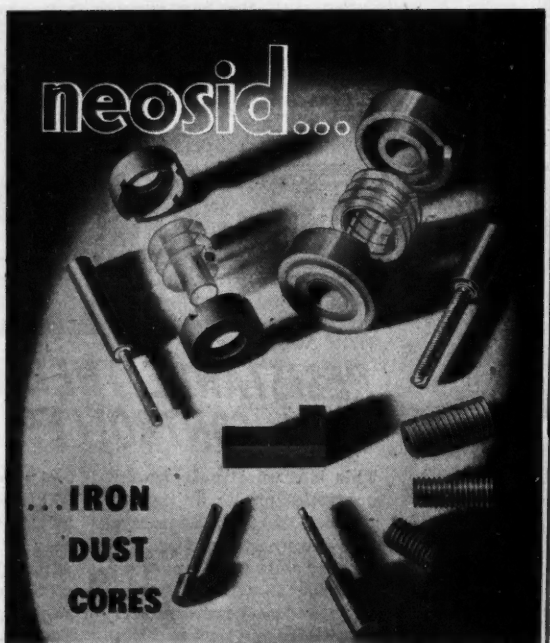

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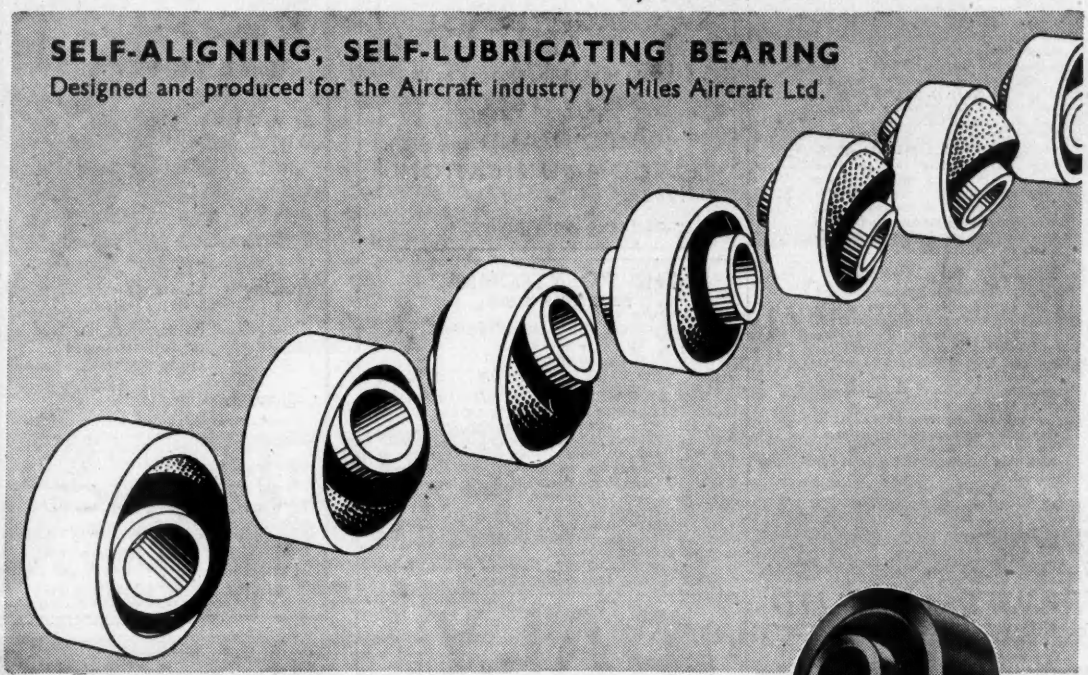

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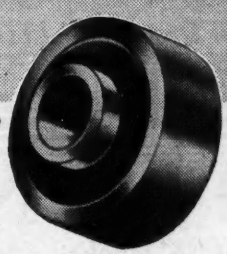

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Partridge News

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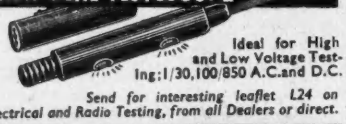

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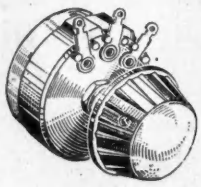

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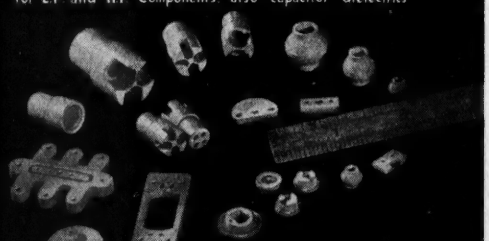

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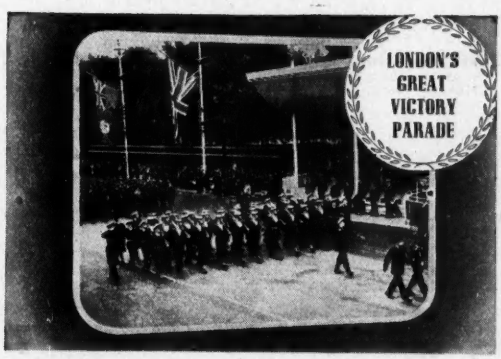

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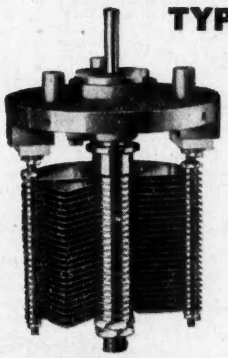

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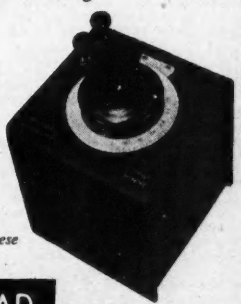

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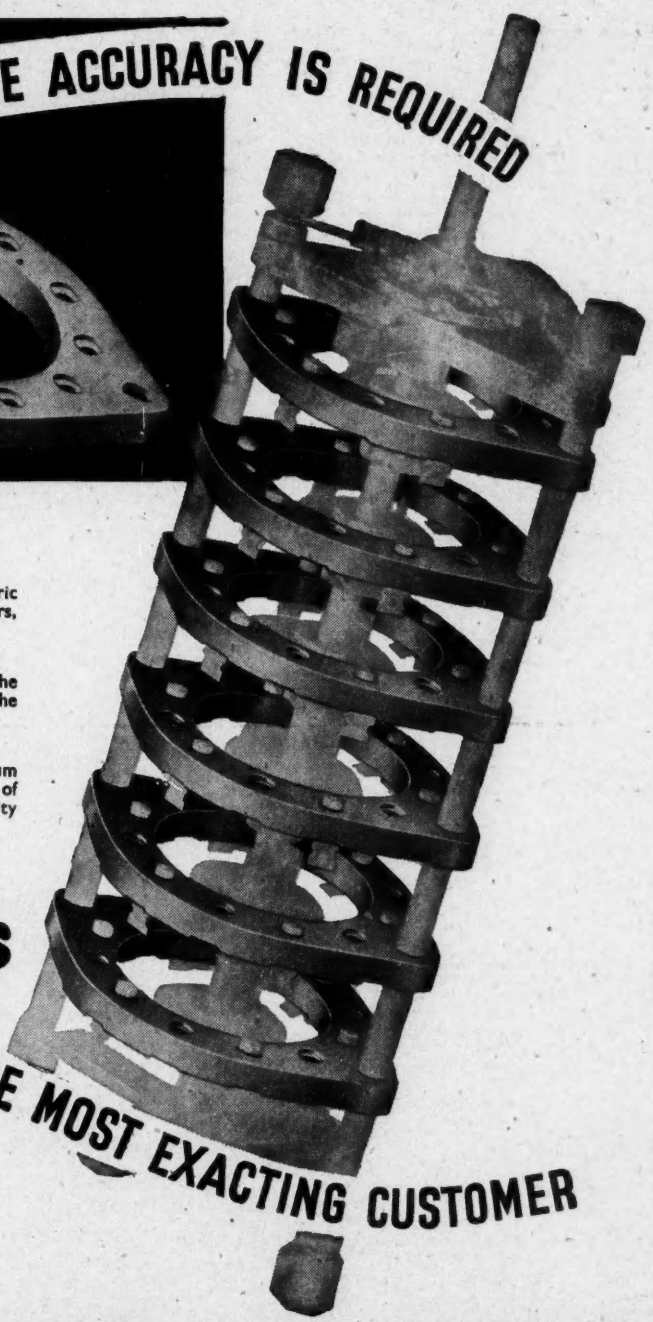

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